Calcasieu Estuary Remedial Investigation/Feasibility Study (RI/FS): Baseline Ecological Risk Assessment (BERA)

Baseline Problem Formulation
Volume I

Prepared for:

Mr. John Meyer, Regional Project Manager
U.S. Environmental Protection Agency, Region 6
1445 Ross Avenue
Dallas, Texas 75202

Prepared – May 2001 (Revised September 2001) – by:

CDM Federal Programs Corporation
600 North Pearl Street, Suite 2170
Dallas, Texas 75201

In Association with:

MacDonald Environmental Sciences Ltd.
2376 Yellow Point Road
Nanaimo, British Columbia V9X 1W5

The Cadmus Group, Inc.
411 Roosevelt Street, Suite 204
Ottawa, Ontario K2A 3X9

CDM
A Subsidiary of Camp Dresser & McKee

consulting
engineering
construction
operations

Plaza of Americas
600 North Pearl St, Suite 2170
Dallas, TX 75201
Tel: (214) 871-9656 Fax: (214) 871-4957

September 12, 2001

Mr. John Meyer
Remedial Project Manager
Environmental Protection Agency, Region 6
1445 Ross Avenue
Dallas, Texas 75202

RAC Contract No. 68-W5-0022
Work Assignment No. 041-RICO-06ZZ

Subject: Problem Formulation for the Calcasieu Estuary, Lake Charles, Louisiana

Dear Mr. Meyer:

Please find attached the revised Problem Formulation for the Calcasieu Estuary RI/FS, Lake Charles, Louisiana. The document has been sent to you in two volumes; Volume I being the main body of the document and Volume II is associated appendices. As always we appreciate the opportunity to support EPA Region 6 on this challenging and exciting project, if you have any questions, please call me at (214) 871-9656 or Don MacDonald at (250) 722-3631.

Sincerely,

for
Mitchell S. Goldberg
Senior Project Manager

Don MacDonald
Senior ERA Specialist

cc: Tom Reilly, EPA Region 6 Project Officer
Linda Brown, CDM Federal
Rich Culver, CDM Federal
Project Files

Calcasieu Estuary Remedial Investigation/Feasibility Study (RI/FS): Baseline Ecological Risk Assessment (BERA)

Baseline Problem Formulation
Volume I

Prepared for:

Mr. John Meyer, Regional Project Manager
U.S. Environmental Protection Agency, Region 6
1445 Ross Avenue
Dallas, Texas 75202

Prepared – May 2001 (Revised September 2001) – by:

D.D. MacDonald[1], D.R.J. Moore[2], A. Pawlisz[2], D.E. Smorong[1], R.L. Breton[2], D.B. MacDonald[2], R. Thompson[2], R.A. Lindskoog[1], M.A. Hanacek[1], and M.S. Goldberg[3]

[1]**MacDonald Environmental Sciences Ltd.**
2376 Yellow Point Road
Nanaimo, British Columbia V9X 1W5

[2]**The Cadmus Group, Inc.**
411 Roosevelt Street, Suite 204
Ottawa, Ontario K2A 3X9

[3]**CDM Federal Programs Corporation**
600 North Pearl Street, Suite 2170
Dallas, Texas 75201

Table of Contents

List of Tables

List of Figures

List of Acronyms

%	percent
ACGIH	American Conference of Governmental Industrial Hygienists, Inc
AQUIRE	Aquatic Toxicity Information Retrieval System
AHH	aryl hydrocarbon hydroxylase
ASTM	American Society for Testing and Materials
ATSDR	Agency for Toxic Substances and Disease Registry
BCF	bioconcentration factor
BEHP	bis(2-ethylhexyl)phthalate
BERA	baseline ecological risk assessment
BI	bioavailability index
BSAF	biota-sediment bioaccumulation factor
BW	body weight
CA	California
CAS	Chemical Abstracts Service
CCC	criterion continuous concentration
CCME	Canadian Council of Ministers of the Environment
CCREM	Canadian Council of Resource and Environment Ministers
CDM	CDM Federal Programs Corporation
CERCLIS	Comprehensive Environmental Response, Compensation, and Liability Information System
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980, 42 U.S.S. 9601 et seq.
CIS	Camford Information Services, Inc.
CLP	Contract Laboratory Program
cm	centimeter
CMA	Chemical Manufacturer's Association
CMC	criteria maximum concentration
CO	Colorado
COPC	contaminant of potential concern
Cr	chromium
Cr(III)	trivalent chromium
Cr(IV)	hexavalent chromium
Cu	copper
DCE	1,2-dichloroethane
DEHP	di(2-ethylhexyl)phthalate; synonym of BEHP
DELT	deformities, fin erosion, lesions, and tumors
DL	detection limit
DNA	deoxyribonucleic acid
DO	dissolved oxygen
DQO	data quality objectives
DW	dry weight
EC_{50}	median effect concentration
EDC	ethylene dichloride
EDTA	ethylenediaminetetraacetic acid

Eh	oxidation/reduction potential
ERA	ecological risk assessment
ERM	effects range median
EROD	ethoxyresorufin *O*-deethylase
ETAG	Ecological Technical Assistance Group
FDA	Food and Drug Administration
FS	feasibility study
g/L	grams per liter
g/m^3	grams per cubic meter
g/mole	grams per mole
g/kg	grams per kilogram
HASP	health and safety plan
HCB	hexachlorobenzene
HCBD	hexachlorobutadiene
Hg	mercury
HMW-PAHs	high molecular weight polycyclic aromatic hydrocarbons
HSDB	hazardous substance databank
IARC	International Agency for Research on Cancer
IPCS	International Program on Chemical Safety
IRIS	Integrated Risk Information System
ITEF	international toxicity equivalency factor
kg	kilogram
K_{oc}	organic carbon partition coefficient
K_{ow}	octanol/water partition coefficient
LA	Louisiana
LC_{50}	median lethal concentration
LCL	lower confidence limit
LD_{50}	median lethal dose
LDEQ	Louisiana Department of Environmental Quality
LMW-PAHs	low molecular weight polycyclic aromatic hydrocarbons
LNHP	Louisiana Natural Heritage Program
LOAEL	lowest observed adverse effect level
LOEC	lowest observed effect concentration
MESL	MacDonald Environmental Sciences Ltd.
mg	milligram
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
mg/m^3	milligrams per cubic meter
mm	millimeter
MFO	mixed function oxidase
mPa	millipascals (standard international unit for pressure)
MS	matrix spike
MSD	matrix spike duplicate
NAS	National Academy of Sciences
ng	nanogram
NG	no guideline
Ni	nickel

NIOSH	National Institute for Occupational Safety and Health
NOAA	National Oceanic and Atmospheric Administration
NOAEL	no observed adverse effect level
NPDES	National Pollutant Discharge and Elimination System
NPL	National Priorities List
NRC	National Research Council
NRCC	National Research Council of Canada
NTP	National Toxicology Program
OC	organic carbon
OH^-	hydroxide
Pa	pascals (standard international unit for pressure)
PAH	polycyclic aromatic hydrocarbon
Pb	lead
PCB	polychlorinated biphenyl
PCDD	polychlorinated dibenzo-*p*-dioxin
PCDF	polychlorinated dibenzofuran
PCS	Permit Compliance System
PEC	probable effect concentration
PEL	probable effect level
ppb	parts per billion
ppm	parts per million
QA/QC	quality assurance/quality control
QAPP	quality assurance project plan
QMP	quality monitoring program
QP	quality procedure
RCRA	Resource Conservation and Recovery Act
RI	remedial investigation
RNA	ribonucleic acid
ROI	receptors of interest
RTECS	Registry of Toxic Effects of Chemical Substances
SAP	sampling and analysis plan
SD	standard deviation
SERA	screening level ecological risk assessment
SMDP	scientific management decision point
SO_4^-	sulfate
SPF	specific pathogen free
SRI	Stanford Research Institute
SQG	sediment quality guideline
STORET	Storage and Retrieval System for water quality data
SVOCs	semi-volatile organic compounds
TAL	target analyte list
TCA	trichloroethane
TEF	toxic equivalency factor
TEQ	toxic equivalents
TOC	total organic carbon
TRI	Toxic Release Inventory
TU	toxic units

UCL	upper confidence limit
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
µg/kg	micrograms per kilogram
µg/L	micrograms per liter
µmol/g	micromoles per gram
VOCs	volatile organic compounds
WHO	World Health Organization
WQC	water quality criteria
WW	wet weight
Zn	zinc

Glossary of Terms

Acute toxicity threshold – The concentration of a substance above which adverse effects are likely to be observed in short-term toxicity tests.

Acute toxicity – The immediate or short-term response of an organism to a chemical substance. Lethality is the response that is most commonly measured in acute toxicity tests.

Adverse effects – Any injury (i.e., loss of chemical or physical quality or viability) to any ecological or ecosystem component, up to and including at the regional level, over both long and short terms.

Ambient – Of or relating to the immediate surroundings.

Aquatic organisms – The species that utilize habitats within aquatic ecosystems (e.g., aquatic plants, invertebrates, fish, amphibians and reptiles).

Aquatic-dependent species – Species that are dependent on aquatic organisms and/or aquatic habitats for survival.

Aquatic-dependent wildlife – Wildlife species that are dependent on aquatic organisms and/or wildlife habitats for survival, including fish, amphibians, reptiles, birds, and mammals (e.g., egrets, herons, kingfishers, osprey, racoons, mink, otter; see Figure 7.2).

Aquatic ecosystem – All the living and nonliving material interacting within an aquatic system (e.g., pond, lake, river, ocean).

Aquatic invertebrates – Animals without backbones that utilize habitats in freshwater, estuaries, or marine systems.

Benchmarks – Guidelines that are intended to define the concentration of a contaminant that is associated with a high or a low probability of observing harmful biological effects or unacceptable levels of bioaccumulation.

Benthic invertebrate community – The assemblage of sediment-dwelling organisms that are found within an aquatic ecosystem.

Bioaccumulation – The net accumulation of a substance by an organism as a result of uptake from all environmental sources.

Bioaccumulative substances – The chemicals that tend to accumulate in the tissues of aquatic and terrestrial organisms.

Bioavailability – Degree to which a chemical can be absorbed by and/or interact with an organism.

Bioconcentration – The accumulation of a chemical in the tissues of an organism as a result of direct exposure to the surrounding medium (i.e., it does not include food web transfer).

Biological half-life – The time required for one-half of the total amount of a particular substance in a biological system to be consumed or broken down by biological processes.

Biomagnification – The accumulation of a chemical in the tissues of an organism as a result of food web transfer.

Brackish marsh – A marsh of low salinity, usually up to 5 parts per thousand during the period of average annual low flow.

Brood – The young animals produced during one reproductive cycle.

Calanoid (copepods) – Small crustaceans, 1-5 mm in length, commonly found as part of the free-living zooplankton in freshwater lakes and ponds.

Catabolism – The phase of metabolism which consists in breaking down of complex substances into simpler substances.

Chelating agent – An organic chemical that can bond with a metal and remove it from a solution.

Chronic toxicity – The response of an organism to long-term exposure to a chemical substance. Among others, the responses that are typically measured in chronic toxicity tests include lethality, decreased growth, and impaired reproduction.

Chronic toxicity threshold – The concentration of a substance above which adverse effects on sediment-dwelling organisms are likely to occur in longer-term toxicity tests.

Colloids – Very small, finely divided solids (that do not dissolve) that remain dispersed in a liquid for a long time due to their small size and electrical charge.

Confluence – The location where two waterways meet.

Congener – A member of a group of chemicals with similar chemical structures (e.g., PCDDs generally refers to a group of 75 congeners that consist of two benzene rings connected to each other by two oxygen bridges).

Contaminants of potential concern – The substances that occur in environmental media at levels that pose a potential risk to ecological receptors or human health.

Contaminated sediment – Sediment that contains chemical substances at concentrations that could harm sediment-dwelling organisms, wildlife, or human health.

Cracking catalysts – Substances that speed-up petroleum refining processes (used to "crack" crude oil into gasoline, jet fuel, kerosene, diesel fuel, and other petroleum products).

Degradation – A breakdown of a molecule into smaller molecules or atoms.

Demethylated – Removal of a methyl group from a chemical compound.

Diagenesis – The sum of the physical and chemical changes that take place in sediments after its initial deposition (before they become consolidated into rocks, excluding all metamorphic changes).

Dimorphic – Existing in two forms (e.g., male and female individuals in animals).

Endpoint – A measured response of a receptor to a stressor. An endpoint can be measured in a toxicity test or a field survey.

Estivate – To pass the summer or dry season in a dormant condition.

Fumarolic – Describes a vent in or near a volcano from which hot gases, especially steam are emitted.

Gavage – Forced feeding by means of a tube inserted into the stomach through the mouth.

Genotoxic – Describes the toxic effects of a substance which damages DNA.

Half-life – The length of time required to reduce the concentration of a substance by 50% in a particular medium.

Halogenated aliphatic compound – A chemical compound with a halogen atom (F, Cl, Br, I) associated with an alkane chain.

Hepatomegaly – A condition in which the liver is enlarged beyond its normal size.

Hepatotoxic – Refers to anything which poisons the liver.

Hibernate – To pass the winter in a dormant condition, in which metabolism is slowed down.

Homeostasis – The maintenance of metabolic equilibrium within an animal.

Hyperplasia – An abnormal multiplication or increase in the number of normal cells in a tissue.

Hypertrophy – Enlargement of an organ resulting from an increase in the size of the cells.

Lethal dose – The amount of a chemical necessary to cause death.

Littoral (vegetation) – Pertaining to or along the shore.

Marine – Relating to the sea.

Mast – The fruit of forest trees.

Microsomal – Describing the membrane-bound vesicles that result from the fragmentation of the endoplasmic reticulum.

Miscible – Capable of being mixed.

Morphometry (bone) – The quantitative study of the geometry of bone shapes.

Necrosis – Necrosis is the death of plant or animal cells or tissue.

Neoplastic – Refers to abnormal new growth.

Neotenic (salamander) – The retention of juvenile characteristics in the adult individual.

Nephrotoxic – Refers to anything that poisons the kidney.

Order of magnitude – A single exponential value of the number ten.

Organogenesis – The basic mechanisms by which organs and tissues are formed and maintained in an animal or plant.

Osmoregulation – The control of the levels of water and mineral salts in the blood

Pannes – Bare, exposed, or water-filled depressions in marshes

Partition coefficient – A variable that is used to describe a chemical's lipophilic or hydrophobic properties.

Petechial (hemorrhages) – A minute discolored spot on the surface of the skin or mucous membrane, caused by an underlying ruptured blood vessel.

Photolysis – Chemical decomposition caused by light or other electromagnetic radiation.

Porphyria – A hereditary disease of body metabolism that is caused by a change in the amount of porphyrins (nitrogen-containing substances) found in the blood.

Pyrolysis – Decomposition of a chemical by extreme heat.

Ranid (frog) – The family of true frogs of the order Anura.

Receiving water – A river, ocean, stream or other watercourse into which wastewater or treated effluent is discharged.

Receptor – A plant or animal that may be exposed to a stressor.

Sediment – Particulate material that usually lies below water.

Sediment-associated contaminants – Contaminants that are present in sediments, including whole sediments or pore water.

Sediment-dwelling organisms – The organisms that live in, on, or near bottom sediments, including both epibenthic and infaunal species.

Seminiferous tubules – The glandular part of testicles that contain the sperm producing cells.

Sorption – The process by which one substance takes up or holds another; adsorption or absorption.

Stressor – Physical, chemical, or biological entities that can induce adverse effects on ecological receptors or human health.

Sublethal dose – The amount, or dosage, of a toxin necessary to cause adverse effects, not including death.

Teratogenic – Causing birth defects.

Terrestrial habitats – Habitats associated with the land, as opposed to the sea or air.

Tissue – A group of cells, along with the associated intercellular substances, which perform the same function within a multicellular organism.

Trophic level – A portion of the food web at which groups of animals have similar feeding strategies.

Volatilization – To change or cause to change from a solid or liquid to a vapor.

Wet deposition – The transfer of an element from the atmosphere to land or water through rain or snow.

Acknowledgments

The authors would like to acknowledge a number of individuals who substantially contributed to the production of this document. First, the conceptual design of the Phase II sampling and analysis program was developed at the ***Calcasieu Estuary Remedial Investigation/Feasibility Study (RI/FS): Baseline Ecological Risk Assessment Workshop***. The individuals who attended that workshop and contributed to the design of the program deserve our sincerest appreciation. These individuals included John Meyer (United States Environmental Agency; USEPA), John Rauscher (USEPA), Ron Gouget (National Oceanic and Atmospheric Administration; NOAA), Chris Ingersoll (United States Geological Survey; USGS), Scott Carr (USGS), Paul Conzelmann [United States Fish and Wildlife Service (USFWS); now with the United States Parks Service], Duane Wilson (Louisiana Department of Environmental Quality; LDEQ), Tom Harris (LDEQ), and Denise Sanger (NOAA; now with South Carolina Department of Natural Resources). In addition, we would like to thank a number of individuals who provided excellent technical reviews of the document, including John Meyer (USEPA), David Charters (USEPA), John Rauscher (USEPA), Susan Roddy (USEPA), and Barry Fosythe (USFWS). Mary Lou Haines provided administrative support during the preparation of this document. Funding for the preparation of this document was provided through a contract to CDM Federal Programs Corporation from the USEPA.

Chapter I Introduction

1.0 Background

The Calcasieu Estuary is located in the vicinity of Lake Charles in Calcasieu Parish, Louisiana (LA; *Figure 1.1*). The Calcasieu River flows some 160 miles from its headwaters to the Gulf of Mexico. The estuarine portion of the watershed extends from the saltwater barrier, north of Lake Charles, to the gulf. The Calcasieu Estuary is characterized by a number of distinctive physical features, including Lake Charles, Prien Lake, Moss Lake, and Lake Calcasieu. The Calcasieu River/Calcasieu Ship Channel is joined by several tributaries within the estuary, the most notable being Bayou Verdine, Contraband Bayou, Bayou d'Inde, and Bayou Olsen. The Intercoastal Waterway connects the Calcasieu Estuary with the Sabine Lake system to the west, and Grand Lake to the east.

The land surrounding the Calcasieu Estuary includes undeveloped, rural residential, commercial, and heavy industrial properties. Heavy industry dominates the southern reaches of Bayous d'Inde and Verdine on both sides. Permitted discharge outfalls (as identified in the National Pollution Discharge Elimination System; NPDES) as well as agricultural and industrial drainage ditches (including the Vista West Ditch, the Faubacher Ditch, and the Kansas City Southern Railroad West Ditch), discharge to the estuary. These discharges (current and historic), stormwater runoff, and accidental spills have contributed to the contamination of surface water, sediment, and biota within the estuary. CDM (1999) reviewed and evaluated the available data on the levels of contaminants in environmental media in the estuary and concluded that exposure to sediment and surface waters pose potential risks to ecological receptors.

In addition to chemical contamination, the Calcasieu Estuary has also been affected by a number of physical alterations. Construction of the Calcasieu Ship Channel (completed in 1941) has altered the salinity regime of the Calcasieu Estuary and impacted marsh areas to the west of Calcasieu Lake. Water control structures were installed by the United States Fish and Wildlife Service (USFWS) to reduce these impacts. Monitoring is currently being conducted by the USFWS to evaluate the effectiveness of these structures. In addition, much of the Calcasieu River and portions of the various bayous contained within the study area were dredged or rerouted during the 1950s. For example, the southernmost 3,500 feet of the Bayou Verdine was rerouted to the west when Olin Corporation (Olin) built the West Pond over the original bayou (PRC 1994). Periodic navigational dredging is conducted in portions of the basin to facilitate access by ocean-going vessels and/or barge traffic. These physical alterations have most certainly contributed to the stresses on this system.

The estuary currently supports a recreational fishery primarily targeted on sea trout, redfish, black drum, and flounder. In addition, commercial fisheries for shrimp and crab exist in the southern portions of the estuary, primarily in the ship channel. However, fish consumption advisories have been issued in the estuary to protect human health from adverse effects associated with the ingestion of contaminated fish (LDEQ 1998a). Although the estuary is not used as a drinking water source, the surface waters have been designated by the Louisiana Department of Environmental Quality (LDEQ) as supporting primary contact recreation, secondary contact recreation, and fish and wildlife propagation (PRC 1994). The Calcasieu Estuary Cooperative Site has not been proposed for inclusion on the National Priorities List (NPL; i.e., sites that require investigation to assess risks to human health and the environment), but has been the subject of numerous environmental studies dating back to the early 1970's.

This document was prepared to support the design and implementation of a baseline ecological risk assessment (BERA), which is being conducted as part of a remedial investigation and feasibility study (RI/FS) of the Calcasieu Estuary. More specifically, this document defines the questions that will be addressed during the BERA, a process that is termed problem formulation. This chapter of the problem formulation document provides an overview of the RI/FS, describes the purpose of the report, and includes a description of the organization of the report.

1.1 Remedial Investigation and Feasability Study (RI/FS)

In response to concerns regarding environmental contamination, an RI/FS is being conducted in the Calcasieu Estuary. (Appendix 1 provides more information on the goals and objectives of the RI/FS). A portion of this study is being designed and implemented to support an ecological risk assessment (ERA) of the Calcasieu Estuary. This ERA is being conducted in accordance with the *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessment* (USEPA 1997a). The United States Environmental Protection Agency (USEPA) guidance document describes an eight-step process for conducting an ERA, including:

Step 1: Screening-Level Preliminary Problem Formulation and Ecological Effects Evaluation;

Step 2: Screening-Level Preliminary Exposure Estimate and Risk Calculation Scientific Management Decision Point (SMDP);

Step 3: Baseline Risk Assessment Problem Formulation SMDP;

Step 4: Study Design and Data Quality Objectives SMDP;

Step 5: Field Verification of Sampling Design SMDP;

Step 6: Site Investigation and Analysis of Exposure and Effects SMDP;

Step 7: Risk Characterization; and,

Step 8: Risk Management SMDP.

In accordance with the USEPA guidance, the Calcasieu Estuary RI/FS is being conducted using this stepwise approach. The objectives of this ERA are:

- To estimate the risks posed by environmental contamination to ecological receptors in the Calcasieu Estuary; and,

- To provide the information needed by risk managers to make decisions regarding the need for remedial actions.

CDM Federal Programs Corporation (CDM) is the primary contractor for USEPA and has made substantial progress on the initial steps of the investigation (i.e., steps 1 and 2). Specifically, the screening-level ecological risk assessment (SERA) has now been completed, including the initial problem formulation, effects evaluation, exposures estimate, and risk calculation. The results of that assessment indicate that there is potential for risk to ecological receptors from exposure to environmental media in the Calcasieu Estuary, including surface water and sediment (CDM 1999). As such, there is a need to conduct a BERA of the Calcasieu Estuary (USEPA 1997a).

To support the RI/FS, detailed information is needed on environmental conditions within the estuary. Such data are usually collected in two stages, a Phase I sampling program to support the SERA and a Phase II sampling program to support the BERA. The Phase I sampling program has been completed, providing detailed information on the nature and extent of contamination. While the results of the Phase I sampling program provide important information for assessing the risks to aquatic and aquatic-dependent receptors associated with environmental contamination, the existing database needs to be augmented to support the BERA.

To identify information needs and associated monitoring strategies for the Phase II sampling program, the USEPA, Region VI convened a BERA workshop in Lake Charles, LA on September 6 and 7, 2000. The workshop participants included representatives of the USEPA, National Oceanic and Atmospheric Administration (NOAA), LDEQ, USFWS and CDM. The workshop was designed to enable participants to articulate the goals and objectives for the ecosystem (i.e., based on the input that had been provided by the community in a series of public meetings), to assess the status of the knowledge base, to clearly define key issues and concerns, and to identify the contaminants and areas of potential concern in the study area. Workshop participants also refined the preliminary assessment endpoints and selected priority measurement endpoints to support the BERA (MacDonald *et al.* 2000a). Collectively, the results of the workshop provided a basis for designing a Phase II sampling program to provide further information on the nature, severity and areal extent of contamination, to assess the bioavailability of environmental contaminants, to evaluate the effects on ecological receptors associated with exposure to contaminants, and to fill outstanding data gaps. See Appendix 1 for more information.

1.2 Purpose of this Report

The workshop summary report (MacDonald *et al.* 2000a) provides essential information for designing the Phase II sampling program of the RI. However, there is a need to further define the scope and goals of the BERA of the Calcasieu Estuary. The process of defining the questions that will be addressed during the BERA is termed *problem formulation*. Problem formulation is a systematic planning process that identifies the factors to be addressed in a BERA and consists of five major activities (USEPA 1997a), including:

- Refinement of the preliminary list of contaminants of ecological concern at the site (i.e., those that were identified during the SERA);
- Further characterization of the potential ecological effects of the contaminants of concern at the site;
- Review and refinement of the information on the fate and transport of environmental contaminants, on potential exposure pathways, and on the biota potentially at risk;
- Selection of assessment and measurement endpoints; and,
- Development of a conceptual model with testable hypotheses (or risk questions) that the site investigation will address.

At the conclusion of the problem formulation, there is a scientific/management decision point, which consists of agreement on four items: the assessment endpoints, the exposure pathways, the risk questions, and the conceptual model that integrates these components (USEPA 1997a).

This document was prepared to define the issues that need to be addressed during the BERA of the Calcasieu Estuary and, in so doing, to establish the goals, scope, and focus of the assessment. The problem formulation document is intended to inform the study design (as defined in the sampling and analysis plan) and data quality objectives process by establishing the measurement endpoints that will be used in the BERA. The information developed during the problem formulation process is intended to provide a basis for evaluating the applicability and implementability of the testable hypotheses, exposure pathway models, and measurement endpoints that have been proposed for the BERA. In this way, the problem formulation document contributes to the development of the sampling design. The problem formulation process is also intended to define how the information collected during the site investigation will be used to characterize exposures, ecological effects, and ecological risks, including associated uncertainties.

1.3 Organization of this Report

This report is organized into a number of sections to facilitate access to the information associated with the problem formulation for the BERA of the Calcasieu Estuary, including:

- Introduction (Chapter 1);
- Geographic Scope of Study Area (Chapter 2);
- Identification of Chemicals of Potential Concern and Areas of Interest in the Calcasieu Estuary (Chapter 3);

- Environmental Fate and Ecological Effects of Contaminants of Potential Concern (Chapter 4);
- Identification of Key Exposure Pathways in the Calcasieu Estuary (Chapter 5);
- Identification of Receptors Potentially at Risk in the Calcasieu Estuary (Chapter 6);
- Overview of Conceptual Site Model (Chapter 7);
- Selection of Assessment and Measurement Endpoints for Evaluating Risks to Ecological Receptors in the Calcasieu Estuary (Chapter 8);
- Risk Analysis Plan and Uncertainty Analysis (Chapter 9);
- References (Chapter 10).

A series of technical appendices are included to provide access to ancillary information related to the Calcasieu Estuary and the RI/FS. Finally, a glossary of terms and a list of acronyms are provided to define the various scientific terms that are used throughout this document.

Chapter 2 Geographic Scope of the Study Area

2.0 Introduction

The Calcasieu River is one of the largest river systems in southwest Louisiana. From its headwaters in the vicinity of Kisatchie National Forest (in Vernon Parish), the Calcasieu River flows some 160 miles to the Gulf of Mexico near Cameron, LA. While much of the Calcasieu River system is relatively uncontaminated, the portion of the watershed from the saltwater barrier near Lake Charles, LA to the Intercoastal Waterway has undergone extensive industrial development over the past five decades. These developmental activities have resulted in widespread contamination in the estuarine portion of the watershed, particularly in the bayous within the upper portion of the estuary (Curry *et al.* 1997).

In response to public concerns, USEPA is conducting a federally-led RI/FS to assess risks to human health and ecological receptors and evaluate remedial options for addressing environmental contamination in the Calcasieu Estuary. Based on the results of the SERA, the portion of the Calcasieu Estuary from the saltwater barrier to Moss Lake was identified as the area in which environmental contamination posed the greatest potential risks to ecological receptors and, as such, was designated as the primary study area (CDM 1999). To facilitate the RI/FS, this study area was divided into three sub-areas, including:

- Upper Calcasieu River;
- Bayou d'Inde; and,
- Middle Calcasieu River.

Several reference areas were also identified in the lower estuary and in the vicinity of Sabine Lake to support the interpretation of the data generated during the RI. Each of these areas are described in the following sections.

2.1 Upper Calcasieu River

The upper Calcasieu River includes the portion of the watershed from the saltwater barrier to the Highway 210 bridge, a distance of roughly 7.5 miles. This portion of the river system consists of several readily identifiable water bodies, including the upper Calcasieu River mainstem from the saltwater barrier to Lake Charles, Lake Charles, Calcasieu Ship Channel from Lake Charles to the Highway 210 bridge, Clooney Island Loop, Contraband Bayou, Coon Island Loop, and Bayou Verdine (*Figure 2.1*).

2.2 Bayou d'Inde

Bayou d'Inde is one of the major tributaries to the Calcasieu River (*Figure 2.2*). From its headwaters near Sulphur, Louisiana, Bayou d'Inde flows in a southeasterly direction some 10 miles to its confluence with the Calcasieu Ship Channel. Over that distance, Bayou d'Inde is joined by several tributaries, the largest of which is Maple Fork. The lower portions of the bayou are characterized by hydraulic connections (i.e., channels that connect the wetlands to the bayou) with a great deal of off-channel wetland habitat, the largest of which is the Lockport Marsh.

2.3 Middle Calcasieu River

The middle Calcasieu River comprises the portion of the watershed from the Highway 210 bridge to the outlet of Moss Lake (a distance of roughly 7.5 miles), excluding Bayou d'Inde (*Figure 2.3*). The primary physiographic features in this portion of the study area include the Calcasieu Ship Channel, Prien Lake, the original Calcasieu River channel, and Moss Lake. For this assessment, the Indian Wells Lagoon and Bayou Olsen were also included in the middle Calcasieu River study area.

2.4 Reference Areas

A total of five areas were selected to represent reference conditions within the Calcasieu River watershed and surrounding environments (*Figure 2.4*). These areas included Bayou Choupique, Grand Bayou, Bayou Bois Connine, Willow Bayou, and Johnson Bayou. Choupique Bayou is located southwest of Moss Lake and flows roughly 5 miles from its headwaters to its confluence with the Intracoastal Waterway northwest of Ellender, LA. Grand Bayou and Bayou Bois Connine are tributaries to Calcasieu Lake, both of which empty into the lake along its eastern shore. Willow Bayou and Johnson Bayou are tributaries to Sabine Lake and discharge into the lake along its southeastern shoreline. All five of these reference areas are relatively pristine and have been virtually unaffected by industrial activities (Ramelow *et al.* 1987).

Chapter 3 Identification of Contaminants of Potential Concern and Areas of Interest in the Calcasieu Estuary

3.0 Introduction

The BERA that is conducted as part of the RI/FS is intended to evaluate the risks posed to ecological receptors associated with exposure to environmental contamination within the Calcasieu Estuary. In addition, the BERA is intended to provide risk managers with the information required to make decisions regarding the need for remedial actions. The problem formulation process provides a basis for systematically planning the various elements of the BERA and communicating this strategy to all stakeholders.

This chapter is intended to provide key background information needed to support the problem formulation for the BERA. More specifically, this chapter provides information on the sources and releases of environmental contaminants in the Calcasieu Estuary. Additionally, this chapter describes the process that was used to identify the contaminants of potential concern (COPCs) in the study area. Finally, the areas of interest within the estuary, as identified during the BERA workshop, are presented (MacDonald *et al.* 2000a).

3.1 Sources and Releases of Environmental Contaminants

There are a number of natural and anthropogenic sources of toxic and bioaccumulative substances in the Calcasieu Estuary. Natural sources of such substances include weathering and erosion of terrestrial soils, bacterial decomposition of vegetation and animal matter, and long-range transport of substances originating from forest fires or other natural combustion sources.

Anthropogenic sources of COPCs in the estuary include industrial wastewater discharges, municipal wastewater treatment plant discharges, stormwater discharges, surface water recharge by contaminated groundwater, non-point source discharges, spills associated with production and transport activities, and deposition of substances that have been released into the atmosphere. The following information was compiled to facilitate assessment of the nature, severity and extent of environmental contamination within the study area.

Industrial activities have been ongoing in the Lake Charles area since the turn of the 20th century. However, construction of the Calcasieu Ship Channel in 1937 transformed Lake Charles into a deep water port. This attribute, in conjunction with the ready availability of oil in the region, set the stage for rapid industrial development in the region. Today, the results of over 50 years of industrial development are evident in the number of sites within the study area that are subject to some form of environmental control or enforcement under federal and state regulatory programs, as follows:

- Based on the information contained in the Permit Compliance System (PCS) database (a national computerized management information system that houses NPDES data), there are at least 103 facilities permitted to discharge effluent into the Calcasieu Estuary. There are potentially 26 additional facilities in the study area permitted to discharge effluent into the Calcasieu Estuary, for which accurate facility locations could not be determined. Of these 103 facilities, 21 are considered to be "major" dischargers (i.e., facilities that discharge a flow greater than one million gallons per day);
- Based on the information contained in the Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS), there are 13 sites within the study area that contain potentially uncontrolled hazardous wastes that require investigation. One of these sites has been proposed for inclusion on the USEPA NPL, which lists the

hazardous waste sites that pose the greatest threat to human health, welfare, and the environment;

- Based on the information contained in the Resource Conservation and Recovery Information System (RCRA Info), there are at least 332 facilities in the study area that are subject to regulation under the Resource Conservation and Recovery Act (RCRA), which means that hazardous wastes are generated, transported, stored, or disposed of at these facilities. There are potentially 18 additional facilities in the study area subject to regulation under the RCRA, for which accurate facility locations could not be determined. Of these 332 facilities, 14 are classified as treatment, storage, or disposal (TSD) facilities; and,
- Based on the information contained in the PCS database, there are three major municipal wastewater treatment plants (WWTPs; serving Sulphur, Lake Charles and Vinton), and seven additional dischargers classified as 'sewerage systems' that have relatively low or unreported flow volumes, that discharge treated effluent into the Calcasieu Estuary. In combination, the WWTPs discharge at least 22.2 million gallons per day into receiving waters. The study area also receives discharges from a number of combined sewer overflow outfalls; however, the numbers, locations, and flow volumes for these point sources have not been determined.

In 1996, NOAA commissioned a study to evaluate the extent of environmental contamination in the Calcasieu Estuary (Curry *et al.* 1997). The results of this investigation indicated that there are nine major industrial point source dischargers within the study area, including:

- PPG Industries;
- Conoco Incorporated;
- Citgo Petroleum Corporation/Cit-Con Oil Corporation;
- CONDEA Vista Company;

- Olin Chemicals;
- OxyChem Petrochemicals;
- Westlake Polymers Corporation;
- Firestone Synthetic Rubber and Latex Company; and,
- W.R. Grace.

The locations of the major industrial and municipal facilities that discharge wastewaters into the Calcasieu Estuary are shown on *Figure 3.1*. The following sections provide background information on the activities that have been and are currently conducted at these facilities and on the nature of contaminant releases that are associated with these facilities (*Table 3.1*).

3.1.1 PPG Industries

PPG Industries owns and operates a chemical manufacturing facility on the west bank of the Calcasieu River at the Coon Island Loop. Chemical manufacturing activities were initiated at the PPG site in the early 1940's. Magnesium was processed at the site until 1947, initially by the United States government and subsequently by Matheson Alkali Works. Between 1947 and 1969, chlorine and caustic soda were produced at the site by Southern Alkali Corporation. PPG Industries acquired full ownership of the site in 1968 and has manufactured a wide variety of chlorinated hydrocarbons (e.g., ethylene dichloride and vinylidene chloride), sodium hydroxide, and precipitated silicas at various times (Curry *et al.* 1997).

PPG Industries discharges substantial volumes of wastewater (i.e., approximately 600,000 liters per minute of treated wastewater) into the PPG canal and Bayou d'Inde (USEPA 2000a). In addition to the contaminants that are released for these permitted outfalls, miscellaneous spills and accidents have resulted in releases of contaminants into surface waters in the vicinity of Bayou d'Inde (Curry *et al.* 1997). Furthermore, PPG also landfilled sludge from the wastewater treatment plant, chlorinated hydrocarbon wastes, and dredge spoils in the South Terminal area until 1980. These activities have resulted in the release of a wide range of chemical substances into surface waters, including copper, lead, mercury, nickel, zinc, chlorinated hydrocarbons, DCE (1,2-dichloroethane), TCA (trichloroethane), HCB (hexachlorobenzene), HCBD (hexachlorobutadiene), sodium hypochlorite, sodium dichromate, sodium hydroxide, trichloroethylene, tetrachloroethylene, perchloroethylene, vinyl chloride, chloroform, bromoform, chlorodibromomethane, di-n-butyl phthalate, and other substances (Curry *et al.* 1997).

3.1.2 Conoco Incorporated

Conoco Incorporated (Conoco) has owned and operated the Conoco Lake Charles Refinery since the early 1940's. The refinery is located on the east side of Bayou Verdine, immediately north of United States Interstate 10. The Conoco facility currently has a capacity of 220,000 barrels of crude oil per day. The products that are manufactured at the refinery include propane, butane, gasoline, kerosene, diesel, lube oil feedstocks, and petroleum coke. Recovered sulfur is processed into sulfuric acid (Curry *et al.* 1997).

Currently, Conoco has eight permitted outfalls, through which treated wastewater is discharged to Bayou Verdine and the Calcasieu River. In addition, numerous spills at the Lake Charles Refinery have resulted in releases of contaminants to Bayou Verdine, Clooney Island Loop, and the Calcasieu River. Some of the substances that are known to have been released from this facility include oil, kerosene, diesel, naphtha, slop oil, DCE, selenium, zinc, bis(2-ethylhexyl)phthalate (BEHP), phenols, dimethyl disulfide, and various polycyclic aromatic hydrocarbons (PAHs) (Curry *et al.* 1997).

3.1.3 Citgo Petroleum Corporation/Cit-Con Oil Corporation

Citgo Petroleum Corporation (Citgo) currently owns and operates the Lake Charles Manufacturing Complex. This facility is located roughly six miles southwest of Lake Charles, LA, on the west bank of the Calcasieu Ship Channel. In the early 1940's, a petroleum refinery was constructed on this site by Cities Service Company to produce aviation fuel. This facility was later expanded by adding a butadiene plant (1949), a lubricating oil plant (1949), a petrochemical plant (1950), and a butyl rubber plant (1963). This facility was acquired by Occidental Petroleum Corporation (OxyChem) in 1982, Southland Corporation in 1983, and a subsidiary of Petroleo de Venezuela S.A. thereafter. The Citgo facility has a rated capacity of 320,000 barrels of crude oil per day, supporting the production of a variety of refined petroleum products (fuel oils, naphtha, petroleum coke, transportation fuels, and gasoline), benzene, methyl-tertiary butyl ether, sulfuric acid, and ethane (Curry *et al.* 1997).

Citgo is authorized to discharge treated process wastewater and stormwater to Bayou D'Inde and the Calcasieu River through a total of 13 outfalls. In addition, a number of spills and accidents at the Citgo facility have resulted in releases of contaminants into these two waterbodies. Some of the substances that have been released from this facility include arsenic, cadmium, chromium, zinc, phenol, 3-methlynonane, chlorine, hydrogen sulfide, phosphoric acid, benzene, ethylbenzene, toluene, ethylene dichloride, naphthalene, polyethylene fibers, gasoline, fuel oil, lubricating oil, neutral oil, crude oil, o-cresol, methyl ethyl ketone, heavy gas oil, coker fuel, and heavy oil (Curry *et al.* 1997). A variety of VOCs and PAHs have also been found in the surge pond (Indian Wells Lagoon), suggesting that these substances have also been released from the facility.

3.1.4 CONDEA Vista Company

CONDEA Vista Corporation (Vista) currently owns and operates the Lake Charles Chemical Complex on a 470 acre site north of Bayou Verdine, between Westlake and

Mosslake, LA. This facility was constructed by Conoco Chemicals in 1961 and sold to E.I. DuPont Nemours and Company in 1981 (Curry *et al.* 1997). In 1984, Vista purchased the Lake Charles facility and subsequently (1991) sold these assets to the German holding company, RWE-DEA. The products that are manufactured at this facility include vinyl chloride monomer, linear alkyl-benzene, normal paraffins, low polynuclear aromatic solvent, linear alcohols, alumina, ethoxylates, and ethylene.

Vista discharges treated wastewater to Bayou Verdine via the West Ditch through their permitted wastewater outfalls. In addition, a number of spills and accidents have resulted in the release of contaminants to Bayou Verdine and the Calcasieu River. Some of the substances that have been released into surface waters from this facility include aluminum, copper, chromium, lead, nickel, zinc, tetrachloroethane, heavy oil, DCE, benzene, toluene, xylene, kerosene, sulfuric acid, sodium hydroxide, chloroform, methyl chloride, vinyl chloride, and vinyl chloride monomer (Curry *et al.* 1997).

3.1.5 Olin Chemicals

Olin Chemicals (Olin) currently owns and operates a 1,200 acre facility on the Clooney Island Loop of the Calcasieu River, roughly one mile west of Lake Charles (Curry *et al.* 1997). In 1934, Olin Chemicals began producing soda ash at its facility in Lake Charles. Since that time, the plant has undergone numerous expansions to facilitate the production of caustic soda, nitrate-based explosives, synthetic ammonia, nitric acid, sodium nitrate, rocket fuel, synthetic anhydrous ammonia, urea, isocyanates, and cyanurate-based swimming pool chemical. During the 1980's, Olin eliminated several product lines including soda ash, caustic soda, sodium nitrate, urea, and ammonia (Curry *et al.* 1997).

Olin is authorized to discharge treated process wastewater and stormwater to Bayou Verdine, the Calcasieu River, and Kelso Bayou through at least three permitted outfalls. Some of the substances that have been discharged to surface waters from this facility include arsenic, nickel, zinc, DCE, tetramethyl piperidinone, chlorophosphate ethanol, BEHP, oil, ammonia, chlorine, chloroform, and monochlorobenzene (Curry *et al.* 1997).

3.1.6 OxyChem Petrochemicals

In 1985, OxyChem purchased an ethylene/propylene and polyethylene manufacturing facility from Cities Service Company. This facility is located south of Bayou d'Inde and west of the Calcasieu River. Originally, the facility encompassed roughly 300 acres and consisted of two polyethylene manufacturing units and two ethylene/propylene manufacturing units. The two polyethylene units were sold to Westlake Polymers in 1987, while one of the ethylene/propylene units was leased to Citgo/Cit-Con. OxyChem operates the remaining ethylene/propylene manufacturing facility under the name Olefins Plant #1. The plant has the capacity to produce 500 million pounds of ethylene and 125 million pounds of propylene annually. Recently, this facility was purchased by Equistar.

OxyChem discharges treated process water, non-process wastewater, and stormwater runoff to Bayou d'Inde through at least three permitted outfalls. Miscellaneous accidents and spills have also resulted in releases of contaminants into surface waters. Some of the substances that have been discharged into Bayou d'Inde from this facility include cadmium, selenium, methylene chloride, naphthalene, BEHP, DCE, oil, sulfuric acid, and benzene (Curry *et al.* 1997).

3.1.7 Westlake Polymers Corporation

Westlake Polymers Corporation (Westlake) owns and operates a polyethylene manufacturing facility in Sulphur, LA. This facility, which is located south of Bayou d'Inde and west of the Calcasieu River, is comprised of two polyethylene production plants that were acquired from OxyChem in 1987. The two plants had a combined production capacity of 700 million pounds of polyethylene annually in 1990. An ethylene vinyl acetate copolymer product is also manufactured at the Westlake facility (Curry *et al.* 1997).

Westlake discharges treated process wastewater and stormwater to Bayou d'Inde through at least five permitted outfalls. Miscellaneous spills and accidents have also resulted in the discharge of contaminants into surface waters. Some of the substances that have been documented in Westlake's effluent discharges include chromium, copper, zinc, bromoform, chloroform, acetone, di-n-butyl phthalate, 2-methly-2-propanol, oil, and BEHP (Curry *et al.* 1997).

3.1.8 Firestone Synthetic Rubber and Latex Company

Firestone Synthetic Rubber and Latex Company (Firestone) owns and operates a rubber and latex manufacturing facility near Sulphur, LA. This facility began operations in 1943 and currently occupies an area of 80 acres south of Bayou d'Inde. The facility produces synthetic rubber and latex which are used in the production of tires and other rubber-based products. The plant has a production capacity of 165,000 tons of synthetic rubber and latex annually. An emulsion synthetic rubber production unit that had been operated at the site was shut down in 1981 (Curry *et al.* 1997).

Firestone is authorized to discharge treated process wastewater and stormwater runoff to Bayou d'Inde through at least three permitted outfalls. Additionally, various contaminants have been released into surface waters in the vicinity of the Firestone facility as a result of miscellaneous spills and accidents. Some of the substances that have been released into Bayou d'Inde from this facility include zinc, di-n-butyl phthalate, styrene, and oil and grease (Curry *et al.* 1997).

3.1.9 W.R. Grace

W.R. Grace currently owns and operates a manufacturing facility in Carlyss, LA. Although there is little information available on this facility, it appears that silica-alumina petroleum cracking catalysts have been produced at this plant since 1953. The facility covers roughly 120 acres and is located near the west bank of the Calcasieu River, south of the Citgo facility (Curry *et al.* 1997).

W.R. Grace discharges treated process wastewater and process area stormwater to Young's Bayou, which flows into the lower Calcasieu River, through at least three permitted outfalls. Some of the substances that have been discharged into surface waters from this facility include aluminum, cadmium, nickel, and zinc (Curry *et al.* 1997). No information was located on the nature or volumes of any accidental spills that have occurred at the W.R. Grace facility.

3.1.10 Summary of Sources

The results of the review that was conducted for NOAA (Curry *et al.* 1997), demonstrate that there are many industrial sources of contaminants in the Calcasieu Estuary. The substances and /or classes of substances that have been released into surface waters from these sources are identified in *Table 3.1*. A listing of the substances that have been released into various waterbodies within the Calcasieu Estuary is provided in *Table 3.2*.

3.2 Contaminants of Potential Concern in the Study Area

The identification of chemicals and areas of potential concern represents an essential element of the problem formulation process (USEPA 1998a). To initiate this process, CDM conducted a SERA of the Calcasieu Estuary in 1999 to assess the potential for adverse biological effects on ecological receptors associated with either direct or indirect exposure to contaminated environmental media in the Calcasieu Estuary (CDM 1999). To support this assessment, historical data on the levels of environmental contaminants in surface water, sediment, and biota were collated and compiled (CDM 1999). Subsequently, the maximum measured concentration of each substance in each media type was compared to the lowest ecological screening value for that substance to facilitate the determination of maximum hazard quotients. These maximum hazard quotients provided a basis for identifying the substances in Calcasieu Estuary surface water, sediment, and biota that occurred at levels sufficient to potentially adversely affect one or more ecological receptors. These substances were termed contaminants of potential concern (COPCs) in the Calcasieu Estuary and included: metals; PAHs; PCBs (polychlorinated biphenyls); organochlorine and other pesticides; chlorophenols; chlorinated benzenes; chlorinated ethanes; phthalates; cyanide; and acetone (*Tables 3.3 to 3.6*).

Because the preliminary list of COPCs that emerged from the SERA contained over 100 substances (CDM 1999), it was determined that it required further refinement to assure that it included only those substances with a relatively high probability of adversely affecting ecological receptors. For this reason, a scoping meeting was convened in Denver, Colorado (CO) in July, 2000 to develop a more focused list of COPCs. The scoping meeting was attended by risk assessors, risk managers, and the USEPA Region VI Ecological Technical Assistance Group (ETAG). Rather than relying on historical data (as was done in the SERA), the participants at this scoping meeting used the results of the Phase I sampling program of the RI to identify the COPCs in the Calcasieu Estuary (Goldberg 2001). For water-borne contaminants, the substances that occurred in unfiltered water samples at total concentrations in excess of the ambient water quality criteria (i.e., final chronic values, which are termed criteria continuous concentrations, or CCCs; USEPA 1999a) were deemed to be COPCs. For sediment-associated constituents, the substances that occurred in whole sediments at concentrations in excess of the effects range median values (ERMs; Long *et al.* 1995) or comparable sediment quality benchmarks (i.e., probable effect levels PEL; MacDonald *et al.* 1996; CCME 1999) were considered to be

COPCs. Based on the results of these evaluations, the scoping meeting participants agreed that the following substances were the primary COPCs in the Calcasieu Estuary:

Water-Borne COPCs

- metals [copper (Cu) and mercury (Hg)];
- 1,2-dichloroethane (DCE); and,
- trichloroethane (TCA)

Sediment-Associated COPCs

- metals [copper (Cu), chromium (Cr), lead (Pb), Hg, nickel (Ni), and zinc (Zn)];
- polycyclic aromatic hydrocarbons (PAHs; acenaphthene, acenaphthylene, anthracene, fluorene, 2-methylnaphthalene, naphthalene, phenanthrene, benz[a]anthracene, benzo(a)pyrene, chrysene, dibenz[a,h]anthracene, fluoranthene, pyrene, total PAHs, and other PAHs);
- polychlorinated biphenyls (PCBs);
- polychlorinated dibenzo-*p*-dioxins (PCDDs), and, polychlorinated dibenzofurans (PCDFs);
- chlorinated benzenes [(hexachlorobenzene (HCB), hexachlorobutadiene (HCBD), and degradation products];
- phthalates [bis(2-ethylhexyl)phthalate (BEHP)];
- carbon disulfide;
- unionized ammonia;
- hydrogen sulfide;
- acetone; and,
- organochlorine pesticides (aldrin and dieldrin).

The substances of greatest concern to aquatic-dependent wildlife are those that are persistent and bioaccumulative. The COPCs identified for water and sediment included all of the persistent and bioaccumulative substances (e.g., PCBs, PCDDs, PCDFs, HCB, HCBD, organochlorine pesticides) that had been regularly detected in monitoring studies of the Calcasieu Estuary. Therefore, no additional screening analyses were conducted to identify COPCs for wildlife (i.e., because they were deemed to be unnecessary).

3.3 Areas of Interest within the Study Area

The areas of interest with respect to environmental contamination were identified using an approach that was similar to the one that was used to identify the COPCs. Specifically, the areas in which concentrations of one or more sediment-associated substances exceeded the ERM (Long et al. 1995; Long and Morgan 1991) or a comparable benchmark were considered to be areas of interest. The areas of interest that were identified by workshop participants included (*Figure 3.2*):

- Lower Bayou Verdine (i.e., downstream of the west ditch; COPCs included Cr, Cu, Zn, PAHs, and DCE);
- Upper Bayou Verdine (i.e., upstream of the west ditch; COPCs included PAHs);
- Clooney Island Loop (COPCs included PAHs);
- Clooney Island Loop Barge Slip (COPCs included Cr, Zn, and PCBs);
- Coon Island Loop Northeast (COPCs included PAHs and PCBs);
- Coon Island Loop Southwest (COPCs included PAHs);
- Lower Bayou d'Inde (i.e., mouth to the first bridge over the bayou, including the PPG canal; COPCs included Cu, Cr, Pb, Hg, Ni, Zn, PAHs, PCBs, PCDDs/PCDFs, HCB, HCBD, acetone, aldrin, and dieldrin);
- Middle Bayou d'Inde (COPCs included Ni, Pb, and PCBs);
- South Prien Lake (COPCs included BEHP); and,

- Indian Wells Lagoon Outflow (COPCs included Cu, Pb, Hg, PAHs, and PCBs).

Many aquatic-dependent wildlife species have broad foraging ranges or they prey upon highly mobile species (e.g., fish). Thus, the exposure and risk analyses for wildlife species will not be confined only to these areas of interest.

Chapter 4 Environmental Fate and Ecological Effects of Contaminants of Potential Concern

4.0 Introduction

A stressor is any physical, chemical, or biological entity that has the potential to cause a change in the ecological condition of the environment (USEPA 2000b). Accurate identification of the stressor or stressors that are causing or substantially contributing to biological impairments in aquatic ecosystems is important because it provides a basis for developing strategies that are likely to improve the quality of aquatic resources (USEPA 2000b). In this way, limited human and financial resources can be directed at the challenges that are most likely to maintain or restore beneficial uses.

The RI of the Calcasieu Estuary Cooperative Site has focussed on the identification of the chemical stressors that are posing a potential risk to ecological receptors. Many physical (e.g., water temperature, salinity, dissolved oxygen, erosion and sedimentation, habitat degradation, and pH) and biological (e.g., introduced species, recreational and commercial fishing, disease) factors also have the potential to adversely affect aquatic organisms and aquatic-dependent wildlife species. However, quantification of the effects of these factors on key ecological receptors is outside the scope of the BERA. The strategy for addressing this apparent limitation of the BERA involves assessing risks to ecological receptors in the study areas relative to the comparable risks to those receptors in reference areas. In this way, we will estimate the incremental risks (i.e., or additional risks, which is often referred to as) risk) posed by COPCs above that posed by physical and biological stressors in the systems. In addition, any unaccounted effects of such factors on the measurement endpoints will be addressed in the associated uncertainty analysis (see Section 9.3).

This section of the problem formulation document is intended to support the identification of exposure pathways and receptors at risk for each of the COPCs in the Calcasieu Estuary. Accordingly, the available information on the identity, fate and transport, toxicity, and bioaccumulation of the COPCs that were identified in the SERA (CDM 1999) and subsequent analytical activities are summarized in this section (Goldberg 2001). The rationale for selecting the following COPCs for consideration in the BERA is provided in Section 3.2 (MacDonald *et al.* 2000a; Goldberg 2001). The reader is directed to Appendices 2 to 17 for more detailed information on the environmental fate and effects of the COPCs.

4.1 Copper (Cu)

Copper may be released into the environment from a variety of agricultural, municipal, and industrial sources. In aquatic systems, Cu tends to become associated with dissolved materials or suspended particles, including both organic or inorganic substances. Over time, these forms of Cu tend to become associated with biological tissues and bottom sediments.

Copper is highly toxic to aquatic organisms (particularly the dissolved form), causing effects on the survival, growth, and reproduction of fish, invertebrates, and plants. Exposure to elevated levels of sediment-associated Cu causes acute (i.e., short-term) and chronic (i.e., long-term) toxicity to sediment-dwelling organisms. While avian and mammalian wildlife species tend to be less sensitive to the effects of Cu than are aquatic organisms, dietary exposure to elevated levels of Cu can cause organ damage, reduced growth, and death. See Appendix 2 for more information on the environmental fate and effects of Cu.

4.2 Chromium (Cr)

Chromium may be released into the environment from a number of municipal and industrial sources. Trivalent Cr, Cr(III), and hexavalent Cr, Cr(VI), are the two principal forms of Cr in the environment. The fate of Cr in aquatic systems varies depending on the form of the metal that is released and the environmental conditions in the receiving water system. Generally, Cr(III) forms associations with sediment, while Cr(VI) remains in the water column.

Both forms of Cr are toxic to aquatic organisms, with Cr(VI) being the more toxic of the two. Dissolved Cr is highly toxic to aquatic plants and invertebrates, with short- and long-term exposures causing adverse effects on survival, growth, and reproduction. Fish are generally less sensitive to the effects of Cr than are invertebrates. Exposure to elevated levels of sediment-associated Cr causes acute and chronic toxicity to sediment-dwelling organisms. Dietary exposure to Cr can also adversely affect survival, growth, and reproduction in avian and mammalian wildlife species. See Appendix 3 for more information on the environmental fate and effects of Cr.

4.3 Lead (Pb)

Although Pb may be released into the environment from natural sources, most of the Pb that occurs in aquatic systems has been released due to human activities. Depending on the form of Pb that is discharged, Pb can remain dissolved in the water column or become associated with sediments upon release to aquatic systems.

While dissolved Pb is not highly acutely toxic to aquatic organisms, longer-term exposure to relatively low levels of this substance can adversely affect the survival, growth, and reproduction of fish, invertebrates, and, to a lesser extent, aquatic plants.

Exposure to elevated levels of sediment-associated Pb causes acute and chronic toxicity to sediment-dwelling organisms. In birds and mammals, dietary exposure to elevated levels of Pb can cause damage to the nervous system and major organs, reduced growth, impaired reproduction, and death. The organic forms (i.e., associated with carbon) of Pb tend to be more toxic than the inorganic forms (i.e., Pb salts). See Appendix 4 for more information on the environmental fate and effects of Pb.

4.4 Mercury (Hg)

Natural sources, such as volcanic activity, weathering, and releases from oceans, are known to release Hg into the environment. However, far greater amounts of Hg are released due to anthropogenic activities, such as coal combustion, chemical manufacturing (e.g., chlorine and alkali production from chlor-alkali plants), and non-ferrous metal production, waste incineration, and the dumping of sewage sludge. Upon release into the environment, Hg can remain in the water column, become associated with sediments or accumulate in the tissues of aquatic and terrestrial organisms. Aquatic plants take up very little Hg from water, air, and sediments. For aquatic animals such as fish and invertebrates, the primary routes of exposure include the direct uptake of Hg from surrounding water via the gills, skin, and the gut, as well as the consumption of contaminated prey.

Mercury has the potential to cause a wide range of adverse effects in aquatic and terrestrial organisms, with methylmercury (the principal organic form of the substance) being the most toxic. The effects of Hg poisoning in fish and wildlife include altered behavior and physiology, reduced reproduction, impaired growth and development, and death. Of the forms of Hg that are present in the environment, methylmercury is the most potent form. Top level predators, especially fish-eating birds and mammals are at the highest risk of exposure and resulting adverse effects.

See Appendix 5 for more information on the environmental fate and effects of Hg.

4.5 Nickel (Ni)

Nickel is released into the environment from natural sources and human activities, with the burning of fossil fuels and the processing of Ni-bearing ores being the most important sources. Unlike many other metals, Ni is considered to be highly mobile in aquatic ecosystems, repeatedly cycling between the water column, bottom sediments, and biological tissues.

While there is little information available with which to assess the effects of sediment-associated Ni, exposure to dissolved Ni is known to adversely affect the survival, growth, and reproduction of amphibians, fish, invertebrates, and aquatic plants. In birds and mammals, dietary exposure to elevated levels of Ni can result in reduced growth and survival. See Appendix 6 for more information on the environmental fate and effects of Ni.

4.6 Zinc (Zn)

Zinc is released into the environment as a result of various human activities, including electroplating, smelting and ore processing, mining, municipal wastewater treatment, combustion of fossil fuels and solid wastes, and disposal of Zn-containing materials. In aquatic systems, Zn can be found in several forms, including the toxic ionic form, dissolved forms (i.e., salts), and various inorganic and organic complexes. While Zn can form associations with particulate matter and be deposited on bottom sediments, sediment-associated Zn can also be remobilized in response to changes in physical-chemical conditions in the water body.

The acute toxicity of dissolved Zn is strongly dependent on water hardness, however, chronic toxicity is not. Long-term exposure to dissolved Zn has been shown to adversely affect the survival, growth, and reproduction of fish, invertebrates, and aquatic plants. Exposure to sediment-associated Zn is associated with reduced survival and behavioral alterations in sediment-dwelling organisms. In birds and mammals, dietary exposure to elevated levels of Zn can cause impaired survival, growth, and health. See Appendix 7 for more information on the environmental fate and effects of Zn.

4.7 Polycyclic Aromatic Hydrocarbons (PAHs)

Polycyclic aromatic hydrocarbons are a diverse class of organic compounds that include about one hundred individual substances containing two or more fused benzene, or aromatic, rings. The term low molecular weight (LMW) PAHs is applied to the group of PAHs with fewer than four rings, while high molecular weight (HMW) PAHs have four or more rings. The LMW PAHs include acenaphthene, acenaphthylene, anthracene, fluorene, naphthalene, 2-methylnaphthalene, and phenanthrene. The HMW PAHs include benz[a]anthracene, benzo[a]pyrene, chrysene, dibenz[a,h]anthracene, fluoranthene, and pyrene.

The behavior of PAHs in surface waters depends on a variety of chemical-specific and site-specific factors, with physical-chemical properties playing an important role in determining their fate in aquatic systems. The PAHs with high solubilities (such as naphthalene) may remain dissolved in surface water, while those with lower solubilities are likely to form associations with colloidal material or suspended particulates. Hence, PAHs are commonly associated with suspended particulates in aquatic systems. While PAHs associated with suspended particulates may be photochemically degraded, biodegraded, transported to other areas, and incorporated into aquatic biota, deposition and consolidation with bedded sediments probably represents the most important environmental fate process. Hence, sediments represent the major environmental sink for these compounds.

Releases of PAHs into aquatic ecosystems pose a number of potential risks to aquatic and terrestrial organisms. Water-borne PAHs can be acutely lethal to invertebrates, fish, and amphibians; long-term exposure to sub-lethal levels can impair survival, growth and reproduction. Similarly, exposure to sediment-associated PAHs can adversely affect the survival, growth, and reproduction of benthic invertebrates. Accumulation of PAHs in the tissues of aquatic organisms can adversely affect the survival and reproduction of aquatic-dependent avian and mammalian wildlife species (i.e., those species that consume aquatic invertebrates and/or fish). See Appendix 8 for more information on the environmental fate and effects of PAHs.

4.8 Polychlorinated Biphenyls (PCBs)

Polychlorinated biphenyls are synthetic substances and are released into the environment solely as a result of human activities. PCBs are widespread environmental contaminants and are commonly detected in air, precipitation, soil, surface water, groundwater, sediment, and living organisms. PCBs released to aquatic systems tend to partition into and become incorporated into sediments. PCBs have a high potential for uptake by aquatic and terrestrial organisms, including fish, birds, mammals, and other wildlife. Due to their chemical stability, PCBs are highly persistent in the environment. Hence, cycling, rather than degradation, represents the most important process affecting PCBs once released into the environment.

The PCBs that are released into aquatic ecosystems pose a number of potential risks to aquatic and terrestrial organisms. Although, water-borne PCBs can be acutely lethal to invertebrates, fish, and amphibians, the primary concerns associated with PCBs are effects on survival, growth and reproduction from long-term exposures. Similarly, exposure to sediment-associated PCBs can adversely affect the survival, growth, and reproduction of benthic invertebrates and, potentially, benthic fish species. Accumulation of PCBs in the tissues of aquatic organisms can adversely affect the survival, growth, and reproduction of aquatic-dependent avian and mammalian wildlife species (i.e., those species that consume aquatic invertebrates and/or fish). See Appendix 9 for more information on the environmental fate and effects of PCBs.

4.9 Polychlorinated Dibenzo-p-dioxins (PCDDs) and Polychlorinated Dibenzofurans (PCDFs)

Polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans represent two groups of aromatic compounds with similar physical and chemical properties. The term PCDDs refers to a group of 75 congeners that consist of two benzene rings that are connected by two oxygen atoms. The term PCDFs refers to a group of 135 aromatic compounds that are comprised of two benzene rings, connected by only one oxygen atom. As few as one or as many as eight chlorine atoms may be attached to the benzene rings in PCDDs and PCDFs.

The PCDDs and PCDFs that are released into aquatic systems tend to be more persistent than those released into the atmosphere. Photolysis and volatilization may result in some degradation of these compounds (particularly in shallow, warm water systems); however, biodegradation is considered to be a relatively minor fate process in water. The majority of the PCDDs and PCDFs that are released into water form associations with dissolved and/or particulate organic matter in the water column. Within days, these substances become associated with suspended and bed sediments. Sediment-associated PCDDs/PCDFs tend to be readily bioavailable and are accumulated in the tissues of aquatic organisms.

Releases of PCDDs and PCDFs into aquatic ecosystems pose a number of potential risks to aquatic and terrestrial organisms. Water-borne PCDDs and PCDFs can be acutely lethal to freshwater fish; however, concerns are primarily associated with long-term exposures that can adversely affect the survival, growth, and reproduction of fish. Similarly, exposure to sediment-associated PCDDs and PCDFs can adversely affect the survival and growth of benthic invertebrates. Accumulation of PCDDs and PCDFs in the tissues of aquatic organisms can adversely affect the survival, growth, and reproduction of aquatic-dependent avian and mammalian wildlife species (i.e., those species that consume aquatic invertebrates and/or fish). See Appendix 10 for more information on the environmental fate and effects of PCDDs/PCDFs.

4.10 Chlorinated Benzenes

Chlorinated benzenes are members of a group of semi-volatile organic compounds (SVOCs) that includes chemicals with one to six chlorine substitutions on the benzene parent molecule, such as hexachlorobenzene (HCB) and hexachlorobutadiene (HCBD).

Hexachlorobenzene – The principal sources of HCB to the environment are associated with the manufacture and use of chlorinated solvents, use of contaminated pesticides, incineration of contaminated wastes, and long-range atmospheric transport. Because it is mobile and resistant to degradation, HCB is widely distributed in the environment. HCB has been detected in groundwater, surface water, and sediments. Benthic organisms may accumulate HCB directly from sediments, while other organisms generally accumulate HCB from water and food which is particularly important for organisms at higher trophic levels in the food web.

Exposure of biota to HCB causes a wide range of adverse effects, including reproductive toxicity, carcinogenicity, genotoxicity, and death. Studies also indicate that HCB adversely affects the immune system.

Hexachlorobutadiene – HCBD is a by-product of manufacturing processes that yield chlorinated hydrocarbons. While wastewater from industrial processes can release HCBD into the environment, waste holding areas represent the most significant sources. Other sources of HCBD include its use as a solvent and a heat transfer liquid. Changes in production processes and improvements in waste treatment facilities have reduced HCBD emissions since the 1980s. HCBD has been detected in surface waters, ground waters, sediments, and soils. Because degradation of HCBD is slow, it can be persistent in anaerobic soils and sediments. The principal route of exposure to HCBD is through direct contact with, and ingestion of, soils and sediments, and through consumption of benthic and soil organisms by species at higher trophic levels.

Bacteria and plants are less sensitive to HCBD than fish or invertebrates. Exposure of birds and mammals to HCBD causes a wide range of adverse effects, including reproductive toxicity, carcinogenicity, genotoxicity, and death. See Appendix 11 for more information on the environmental fate and effects of HCB and HCBD.

4.11 Phthalates

Phthalates belong to the group of chemicals called SVOCs. This diverse group of chemical compounds includes substances that are moderately volatile and may be present in the environment in a variety of forms. Bis(2-ethyl hexyl)phthalate (BEHP) can be released directly into the atmosphere through emissions during the manufacture and use of phthalates and through the incomplete combustion of plastic materials. More than 50% of the BEHP in the atmosphere occurs in the vapor phase, rather than in association with suspended particulate matter. This substance has limited water solubility and a strong tendency to adsorb to suspended sediments in the water column and to bottom sediments.

Toxicity to aquatic organisms has been reported at high concentrations of BEHP, but in studies with rainbow trout no significant adverse effects were detected on hatchability, growth, or survival. Acute toxicity to mammals is also relatively low. Short-term acute toxicity investigations with rats have shown effects related to body weight gain and increases in liver weight. Sub-chronic studies have revealed effects on body weight gain and other physiological effects. Reproductive toxicity and mortality have been observed in mammals at high doses. See Appendix 12 for more information on the environmental fate and effects of BEHP.

4.12 Dichloroethane (DCE)

Chlorinated ethanes are a subgroup of volatile organic compounds (VOCs) that include chemicals with one to six chlorine substitutions on the ethane parent molecule. Atmospheric emissions of DCE account for the majority of releases into the environment. Wastewater releases are the second largest source. Other environmental releases are associated with Pb scavenging, paints, coating, grain fumigation, and cleaning agents (USEPA 1985). The results of some studies suggest that partitioning of DCE to sediments and biota is not an important fate process; however, DCE has the potential to be transported for long distances in the atmosphere.

Once released into the aquatic environment, a significant portion of the DCE remains in the water column. As such, the principal route of exposure to this substance occurs through direct contact and ingestion of contaminated waters. DCE is not highly toxic to biota; however, toxicity to fish has been observed in association with exposure to high concentrations (i.e., >100mg/L) of this substance. The results of short-term and sub-chronic studies indicate that the liver and kidneys are the target organs. Although lethality and reduced growth have been observed in birds and mammals fed relatively high doses of DCE (e.g., 400 to 2,500 mg/kg), reproductive impairment has not been reported. See Appendix 13 for more information on the environmental fate and effects of DCE.

4.13 Trichloroethane (TCA)

Trichloroethane can be released into surface water, air and land in association with various manufacturing processes. TCA is frequently found in ambient air, particularly near industrialized areas. However, it is not often detected in sediments. Volatilization is likely the major process for removal from aquatic ecosystems, with TCA persisting for long periods in the atmosphere. TCA has been detected in several fish species and invertebrates with the major exposure route being through direct contact with, and ingestion of, contaminated waters, as well as through the food chain.

While TCA appears to have a low potential for acute toxicity, short term exposures of fish to TCA produced some behavioral changes, increased respiration, and loss of equilibrium. Rats exhibited mortality when exposed to this substance in long-term tests. Gestation, fetal toxicity, fertility and pup survival and weight gain were unaffected, however. See Appendix 14 for more information on the environmental fate and effects of TCA.

4.14 Carbon Disulfide

Carbon disulfide is a highly mobile and flammable liquid. Pure carbon disulfide is a colorless liquid that is comprised of one carbon atom and two sulfur atoms. Substantial quantities of carbon disulfide are released into the environment, both from anthropogenic and natural sources. At room temperature, carbon disulfide is a liquid that is denser than water and is moderately soluble in water. Carbon disulfide does not form strong associations with organic carbon in soils or sediments or with lipids in biological tissues. Carbon disulfide readily partitions to the atmosphere upon release to water or soil.

Elevated levels of this substance in water can be acutely toxic to aquatic organisms, including fish, invertebrates, and plants. No information was located on the effects of long-term exposures of these receptors to carbon disulfide, however. Considering the physical and chemical properties of this substance, it is unlikely to bioaccumulate in the food web. Hence, consumption of contaminated prey items does not represent a significant route of exposure for fish- or invertebrate-eating birds or mammals. Nevertheless, inhalation could pose risks to wildlife utilizing habitats in the vicinity of release locations. See Appendix 15 for more information on the environmental fate and effects of carbon disulfide.

4.15 Acetone

Acetone is a member of the VOC group of chemicals. This group includes many industrial chemicals and solvents that readily volatilize into the atmosphere. Acetone is released into the air, water, and soil from both natural and industrial sources. High concentrations have been measured in urbanized areas as a result of manufacturing, automobile exhaust, landfills, and waste material burning. Acetone moves easily between air, soil and water.

As acetone does not bind to soil or bioaccumulate in animals, exposure to this chemical results from direct contact and ingestion of contaminated waters. Toxicity to aquatic organisms has been reported in short-term tests. Some of the effects reported in mammalian studies include kidney, liver and nerve damage, birth defects, smaller litters, and impaired reproduction. See Appendix 16 for more information on the environmental fate and effects of acetone.

4.16 Organochlorine Pesticides

Organochlorine pesticides is the term that is commonly applied to a group of substances that are used as pesticides and include one or more chlorine atoms in their molecular structure. Although numerous organochlorine pesticides have been used in the United States over the past 50 years, only two have been identified as COPCs in the Calcasieu Estuary: aldrin and dieldrin.

Aldrin – Aldrin was originally used to control pests in soil, fruit, and vegetables. In 1974, the USEPA banned most of the uses of aldrin due to its suspected carcinogenicity. Ultimately, all uses on food crops were banned. Because it is not produced or imported into the United States, its current use and release into the environment is minimal. Possible new releases may come from the use of old stockpiles of this substance for the underground control of termites. Aldrin is applied to soil and vegetation by injection or aerial spraying. Leaching of aldrin from soils is thought to be minimal; however, soil erosion and sediment transport are major pathways for entry into the aquatic environment. The most likely route of exposure of biota to aldrin is through the consumption of contaminated food and water.

Little information is available on environmental residue levels of aldrin, probably because it is rapidly transformed to dieldrin in the environment. Sunlight and bacteria transform aldrin to dieldrin. Aldrin is moderately to highly toxic to many aquatic and terrestrial organisms. In fish, acutely lethal concentrations of this substance ranged from 2 to 5 :g/L. In mammalian studies, ingestion of aldrin adversely affected survival, growth and a variety of physiological functions.

Dieldrin – Dieldrin was one of the most widely used pesticides in the United States. As a result, dieldrin is found throughout the environment, usually at low levels. Since the use of this chemical was restricted in 1974, domestic releases of dieldrin to the environment have been virtually eliminated. Nevertheless, air, surface water, soil or sediments nearby historic use or disposal sites can contain higher levels of this substance. The most likely route of exposure to dieldrin is through the consumption of contaminated food and water. Since the use of dieldrin continues to be restricted on farm crops, the risk of exposure through these media is typically low.

The pathways for transport of dieldrin include atmospheric dispersion, wind and water erosion of contaminated soil, and resuspension of contaminated stream and lake sediments. Dieldrin can also move through the environment as residues in plants and animals, especially in fish and birds. Dieldrin is moderately to highly toxic to wildlife and aquatic organisms. Studies with animals fed dieldrin have shown that the liver can be damaged and the ability of the immune system to protect against infections can be suppressed. See Appendix 17 for more information on the environmental fate and effects of aldrin and dieldrin.

Chapter 5 Identification of Key Exposure Pathways in the Calcasieu Estuary

5.0 Introduction

As indicated previously, ERA describes the process in which the risks associated with exposure of ecological receptors to contaminated environmental media (i.e., water, sediment, soil, or biological tissues) are estimated. Evaluation of the risks posed by COPCs in the estuary requires a detailed understanding of the pathways through which ecological receptors are exposed to these substances. In turn, the identification of key exposure pathways requires an understanding of the sources and releases of environmental contaminants and the environmental fate of these substances.

5.1 Partitioning of Contaminants of Potential Concern

There are a number of sources of toxic and bioaccumulative substances in the Calcasieu Estuary. Natural sources of such substances include weathering and erosion of terrestrial soils, bacterial decomposition of vegetation and animal matter, and long-range transport of substances originating from forest fires or other natural combustion sources. Anthropogenic sources of environmental contaminants in the estuary include industrial wastewater discharges, municipal wastewater treatment plant discharges, surface water recharge by contaminated groundwater, non-point source discharges, and deposition of substances that have been released into the atmosphere. An overview of the sources of environmental contaminants that have been released into the Calcasieu Estuary is provided in Chapter 3.

Upon release into aquatic ecosystems, these COPCs partition into environmental media (i.e., water, sediment, and/or biota) in accordance with their physical and chemical properties and the characteristics of the receiving water body (see Chapter 4 and Appendices 2 to17 for descriptions of the environmental fate of the COPCs in the estuary). As a result of such partitioning, COPCs can occur at elevated levels in surface water, bottom sediments, and/or the tissues of aquatic organisms. To facilitate the development of conceptual models that link stressors to receptors, the COPCs can be classified into three groups based on their fate and effects in the aquatic ecosystem, including bioaccumulative substances, toxic substances that partition into sediments, and toxic substances that partition into water (including the surface microlayer; *Table 5.1*).

5.2 Overview of Exposure Pathways

Once released to the environment, there are three pathways through which ecological receptors can be exposed to COPCs. These routes of exposure include direct contact with contaminated environmental media, ingestion of contaminated environmental media, and inhalation of contaminated air. The exposures routes that apply to each of the categories of COPCs are described below.

Bioaccumulative Substances – Aquatic organisms and aquatic-dependent wildlife species can be exposed to bioaccumulative substances via several pathways. First, direct contact with contaminated water or sediment can result in the uptake of bioaccumulative substances through the gills or through the skin of aquatic organisms (*Table 5.2*). This route of exposure is particularly important for sediment-dwelling organisms because most of the bioaccumulative COPCs tend to accumulate in sediments upon release into the environment. Ingestion of contaminated sediments and/or prey species also represents an important route of exposure to bioaccumulative substances for aquatic organisms, particularly for sediment-dwelling organisms, carnivorous fish, amphibians, and reptiles (*Table 5.3*).

For aquatic-dependent wildlife species, ingestion of contaminated prey species represents the principal route of exposure to bioaccumulative substances (*Table 5.2*). The groups of wildlife species that are likely to be exposed to bioaccumulative substances through this pathway include insectivorous birds, sediment-probing birds, carnivorous wading birds, piscivorus birds, and omnivorous and piscivorus mammals (*Table 5.3*)

Toxic Substances that Partition into Sediments – Aquatic organisms and aquatic-dependent wildlife species can be exposed to toxic substances that partition into sediments through several pathways. For aquatic organisms, such as microbiota, aquatic plants, sediment-dwelling organisms, benthic fish, and amphibians, direct contact with contaminated sediment and/or contaminated porewater represents the most important route of exposure to toxic substances that partition into sediments (*Table 5.2 and 5.3*). However, ingestion of contaminated sediments can also represent an important exposure pathway for certain species (e.g., polychaetes that process sediments to obtain food). Direct contact with contaminated sediments also represents a potential exposure pathway for reptiles; however, it is less important for reptiles than for other aquatic organisms.

For aquatic-dependent wildlife species, ingestion of contaminated sediments represents the principal route of exposure to toxic substances that partition into sediments. Of the wildlife species that occur in the Calcasieu Estuary, sediment-probing birds are the most likely to be exposed through this pathway (*Table 5.3*).

Toxic Substances that Partition into Surface Water – Aquatic organisms and aquatic-dependent wildlife species can be exposed to toxic substances that partition into surface water through several pathways. For aquatic organisms, such as microbiota, aquatic plants, aquatic invertebrates, fish, and amphibians, direct contact with contaminated water represents the most important route of exposure to toxic substances that partition into surface water (*Table 5.2 and 5.3*). This exposure route involves uptake through the gills and/or through the skin.

For aquatic-dependent wildlife species, ingestion of contaminated water represents the principal route of exposure to toxic substances that partition into surface water. While virtually all aquatic-dependent wildlife species are exposed to toxic substances that partition into surface water, this pathway is likely to account for a minor proportion of the total exposure for most of these species (*Table 5.2 and 5.3*).

Toxic Substances that Partition into the Surface Microlayer – Aquatic organisms and aquatic-dependent wildlife species can be exposed to toxic substances that partition into surface water through several pathways. For aquatic organisms, such as aquatic invertebrates and pelagic fish, direct contact with the contaminated surface microlayer (i.e., the layer of water that is present at the water-air interface) represents the most important route of exposure to such toxic substances (*Table 5.2 and 5.3*). This exposure route involves uptake through the gills and/or through the skin of aquatic organisms.

For aquatic-dependent wildlife species (birds and mammals), inhalation of substances that volatilize from the surface microlayer represents the principal route of exposure to toxic substances that partition into this environmental medium. However, this route of exposure is likely to be of relatively minor importance under most circumstances. This pathway could become important during and following accidental spills, when such substances are present as slicks on the water surface.

Chapter 6 Identification of Receptors Potentially at Risk in the Calcasieu Estuary

6.0 Introduction

A critical element of the problem formulation process is the identification of the receptors at risk that occur within the study area. USEPA guidance is available to help identify receptors at risk (USEPA 1989; 1992; 1997a). The guidance states that receptors at risk include: (1) resident species or communities exposed to the highest chemical concentrations in sediments and surface water; (2) species or functional groups that are essential to, or indicative of, the normal functioning of the affected habitat; and, (3) federal or state threatened or endangered species.

In the Calcasieu Estuary, the ecological receptors potentially at risk include the plants and animals that utilize aquatic, wetland, and terrestrial habitats within the watershed. Based on the results of the SERA (CDM 1999), the ecological receptors that are potentially at risk due to historic and ongoing discharges of contaminants into surface waters are those species that utilize habitats within aquatic and wetland ecosystems. These groups of organisms include microbiota, aquatic plants, benthic macroinvertebrates, zooplankton, fish, reptiles and amphibians, and aquatic-dependent birds and mammals. While other groups of ecological receptors are known to occur within this ecosystem (e.g., terrestrial insects, terrestrial plants), they are considered to be of secondary importance from an aquatic risk assessment perspective due to the low potential for exposure to water-borne or sediment-associated contaminants. The various groups of ecological receptors that occur within the Calcasieu Estuary are described in the following sections.

6.1 Microbial Community

Microbial communities consist of bacteria, protozoans, and fungi and play several essential roles in estuarine ecosystems. Estuaries, in general, and salt marshes, in particular, are widely recognized as highly productive ecosystems (Odum 1975). While phytoplankton (i.e., the algae that is suspended in the water column) and periphyton (i.e., the algae that are attached to the bottom, to plants, or to animals) represent important primary producers (i.e., organisms that transform the sun's energy into organic material) in aquatic ecosystems, marsh grasses (such as *Spartina* sp.) are among the most important in salt marshes. Unlike algae, however, the emergent marsh plants cannot be grazed directly because their tissues are often indigestible to higher order consumers. Consequently, this important source of energy can only be utilized by higher-order consumers after it has been transformed by the microbial community. As such, the microbial community represents an important food source for shrimp, small crabs, worms, shellfish, and snails (Apple *et al.* 2001).

In addition to degrading and transforming detrital organic matter, microbial communities also play a number of key roles in the cycling and transformation of nutrients in sediments and the water column (Odum 1975). For example, the microbial community is an essential component of the nitrogen cycle, in which atmospheric nitrogen is converted, through a series of steps, into nitrates, nitrites, and ammonia. These forms of nitrogen represent essential plant nutrients and are the basic building blocks for protein synthesis (Colinvaux 1973). The sulfur cycle in aquatic environments, in which hydrogen sulfide is converted to sulfate (which is incorporated into plant and animal tissues), is also mediated by the microbial community (Odum 1975). The microbial community also supports primary productivity by transforming phosphorus into forms that can be readily used by aquatic plants (i.e., phosphate). Finally, carbon cycling (i.e., between the dissolved and particulate forms) in aquatic ecosystems is dependent on the microbial community. Although specific information on the composition of microbial communities in the Calcasieu Estuary was not located, it is certain that the microbial community plays an essential ecological role in this watershed.

6.2 Aquatic Plant Communities

The aquatic plant communities in freshwater and estuarine ecosystems consist of phytoplankton, periphyton, aquatic macrophytes, and riparian vegetation. Phytoplankton, the small non-vascular plants that are suspended in the water column, are comprised of several types of algae. While periphyton are also non-vascular plants, they tend to be larger than the plankton forms of algae and grow on other aquatic plants or on the bottom of the watercourse. Aquatic macrophytes is the general term applied to either large vascular or non-vascular plants that grow in freshwater, estuarine, and marine systems (including both submergent and emergent plants). Riparian vegetation is the term that is applied to the vascular plants that grow along the waters edge.

As primary producers, aquatic plants transform the sun's energy into organic matter. Aquatic plants represent a primary food source for a variety of plant-eating invertebrates (i.e., herbivores, which are also known as primary consumers). In addition, aquatic plants provide habitats for a wide variety of species, including aquatic invertebrates. Hence, aquatic plants represent essential components of aquatic ecosystems.

6.2.1 Phytoplankton Communities

Phytoplankton represent an essential component of aquatic food webs because they convert the sun's energy into organic matter, which can then be consumed by zooplankton (i.e., the tiny animals that are suspended in the water column; Odum 1975).

Aquatic plants also provide habitats for many aquatic invertebrate species. In addition, submergent and emergent aquatic plants provide critical spawning and rearing habitats for many estuarine fish species. Many aquatic-dependent wildlife species, such as ducks and geese, rely on habitats created by aquatic vegetation for reproduction and other life history stages.

There are many different species of algae that can comprise phytoplankton communities, which generally fall into seven main groups. The blue-green algae (cyanophyta) are the most primitive group of algae, with a cell structure like that of bacteria (i.e., the cells lack certain membranous structures, such as nuclear membranes, mitochondria, and chloroplasts; Bell and Woodcock 1968). Blue-green algae can occur in unicellular, filamentous, and colonial forms, many of which are enclosed in gelatinous sheathes. Many species of blue-green algae can utilize nitrogen from the atmosphere as a nutrient (termed nitrogen fixation), which makes them adaptable to a variety of environmental conditions.

Green algae (chlorophyta) encompass a large and diverse group of phytoplankton species that are largely confined to freshwater ecosystems. Green algae can occur as single cells, colonies, or filaments of cells. The chrysophytes are comprised of three groups of algae (diatoms - bacillariophyceae; yellow-green algae - xanthophyceae; golden-brown algae - chrysophyceae) which are linked by a common set of features, including a two-part cell wall, the presence of a flagella, the deposition of silica in the cell wall, and the accumulation of the food reserve, leucosin (Bell and Woodcock 1968). The four other groups of phytoplankton include the desmids and the dinoflagellates (i.e., pyrrophytes; which are unicellular, flagellate algae), cryptomonads (i.e., cryptophytes; which are typically flagellate algae that grow well under cold, low light conditions), euglenoids (i.e., euglenophytes; which are unicellular, flagellate algae that are only rarely planktonic), brown algae (i.e., phaeophytes), and red algae (i.e., rhodophytes; Bell and Woodcock 1968).

Maples (1987a) developed a checklist of phytoplankton species for the Calcasieu River/Lake complex, including the Calcasieu River, Contraband Bayou, Bayou d'Inde, Choupique Bayou, and Calcasieu Lake. As part of this study, nine stations were sampled monthly over a two year period by towing a 30 :m mesh plankton net for a one minute period. The results of this investigation indicated that the Calcasieu Estuary supports a diverse phytoplankton community, which is comprised of at least 115 taxa representing 61 genera. The most frequently encountered genera included *Asterionella, Chaetoceros, Coscinodiscus, Navicula, Odontella, Pleurosigma, Rhizoslenia, Skeletonema, Thalassiosira, and Thalassiothix* (Maples 1987a). Information on the ecology of phytoplankton communities in Calcasieu Lake is provided by Maples (1987b).

6.2.2 Periphyton Communities

Periphyton are non-vascular aquatic plants that grow on firm substrates, such as sand, gravel, rocks, shells, and aquatic macrophytes (Bell and Woodcock 1968). Like phytoplankton, periphyton are autotrophic organisms that use the sun's energy to convert inorganic materials (such as carbon, nitrogen, and phosphorus) into organic matter, such as proteins, lipids, and sugars. Periphyton represent an important source of food for benthic and epibenthic invertebrates that feed by grazing on small plants (Odum 1975). Periphyton communities can be comprised of diverse assemblages of algal species, including members of all of the seven groups of algae that comprise phytoplankton communities (Bell and Woodcock 1968).

Based on the results of studies conducted in the early 1980's, it appears that periphyton communities in the Calcasieu Estuary are comprised largely of diatoms and blue-green algae. Maples (1987c) deployed artificial substrates (i.e., glass slides) for two weeks at 14 stations within the study area (i.e., on a quarterly basis throughout 1984), including five stations in Contraband Bayou, four stations in Bayou d'Inde, and five stations in Choupique Bayou. Taxonomic identification of the periphytic diatoms that accumulated on these substrates indicated that at least 99 taxa representing 30 genera occur in these waterbodies. Similar numbers of taxa were observed within each of the three bayous, ranging from 53 taxa in Choupique

Bayou to 61 taxa in Contraband Bayou. The most common genera observed in the study area included *Gomphonema, Navicula, Nitzschia, Cyclotella*, and *Bacillaria.*

As part of a related study, Maples (1987d) collected quarterly periphyton samples in 1984 from three bayous in the study area, including Contraband Bayou, Bayou d'Inde, and Choupique Bayou. In this study, periphyton samples were collected by scraping stones, exposed mud flats, and the stems and leaves of littoral vegetation. The results of this investigation showed that blue-green algae represented important components of the periphyton community. In total, 15 blue-green algae taxa were collected in the three bayous, with the most common genera being *Anacystis, Oscillatoria, Microcoleus*, and *Schizothrix*.

6.2.3 Aquatic Macrophyte Communities

Aquatic macrophyte communities are comprised of large vascular and non-vascular plants that grow in a waterbody. Aquatic macrophytes can grow under the surface of the water (i.e., submergent plants, such as milfoil) or emerge from the surface of the water (i.e., emergent plants, such as bulrushes; Bell and Woodcock 1968).

Aquatic macrophytes play several important roles in freshwater and estuarine ecosystems. As autotrophic organisms, aquatic macrophytes can account for much of the primary productivity in aquatic systems, particularly in wetlands and other shallow areas that favor the establishment of marsh plants. In this role, macrophytes represent an important food source for aquatic organisms, either for grazers that can process these plant materials directly or those species that consume the bacteria that decompose these plant tissues following their death (Odum 1975). In addition, aquatic macrophytes provide habitats that are utilized by a variety of aquatic invertebrate species, including commercially important species such as shrimp and crabs. These habitats can also represent important spawning and nursery areas for many fish species.

Marsh habitats are particularly important in the Calcasieu Estuary. These habitats can be broken down into four general categories based on the extent of saltwater influence, including saline marsh, brackish marsh, intermediate marsh, and fresh marsh (Perret *et al.* 1970). Saline marshes are located in the areas that are directly exposed to saltwater influences, primarily in the lower portions of the estuary. The dominant emergent macrophytes in saline marshes include oystergrass *(Spartina alterniflora*), glasswort (*Salicornia* sp.), black rush (*Juncus roemerianus*), saltwort (*Batis maritima*), and saltgrass (*Distichlis spicata*). Widgeon grass (*Ruppia maritima*) is the dominant species of submerged vegetation in many saline marshes (Perret *et al.* 1970).

Brackish marsh is generally located adjacent to the saline marsh, but is further removed from the sea rim. This is the predominant type of marsh within the Calcasieu Estuary. Wiregrass (*Spartina patens*), threecorner grass (*Scirpus olneyi*), and coco (*Scirpus robustus*) are the most prevalent plant species in brackish marshes. The dominant species of submerged vegetation in brackish marshes is typically widgeon grass (*Ruppia maritima;* Perret *et al.* 1970).

Intermediate marshes are found in the lower salinity areas that occur up-gradient of the brackish marshes. The typical emergent macrophyte species in the intermediate marshes include wiregrass (*Spartina patens*), deer pea (*Vigna repens*), bulltongue (*Sagittaria* sp.), wild millet (*Echinochloa walteri*), bullwhip (*Scirpus californicus*), and sawgrass (*Cladium jamaicense*). Wild celery (*Vallisneria* sp.) and spike rush (Eleocharis sp.) are typically the dominant species of submerged vegetation in intermediate marshes (Perret *et al.* 1970).

Fresh marshes are found in the areas that are not influenced by saltwater intrusion, including those areas upstream of saltwater barriers, at the headwaters of the bayous, and in the vicinity of perched lakes. There are a variety of emergent macrophytes that are typically associated with such fresh marshes, including maiden cane *(Panicum hemitomon*), pennywort (*Hydrocotyl* sp.), pickerelweed (*Pontederia cordata*), alligator weed (*Alternantheria philoxeroides*), bulltongue (*Sagittaria* sp.), and water hyacinth (*Eichhornia crassipes*). The diversity of submergent macrophytes tends to be higher in fresh marshes as compared with the other three marsh types, commonly including fanwort (*Cabomba caroliniana*), coontail (*Ceratophyllum demersum*), bladderwort (*Utricularia vulgaris*), southern naiad (*Najas quadalupensis*), pondweed (*Potamogeton* sp.), and Eurasian milfoil (*Myriophyllum spicatum*; Perret *et al.* 1970).

6.3 Invertebrate Communities

The invertebrate communities in freshwater and estuarine ecosystems consist primarily of zooplankton and benthic macroinvertebrate communities. Zooplankton is the term used to describe the small animals that remain suspended in the water column in aquatic systems. In contrast, benthic macroinvertebrates are the small animals that live in (i.e., infaunal species) or on (i.e., epibenthic species) the sediments in aquatic systems. Aquatic invertebrates (i.e., primary consumers) represent essential elements of aquatic food webs because they consume aquatic plants (i.e., primary producers) and provide an important food source for fish and many other aquatic organisms.

6.3.1 Zooplankton Communities

Zooplankton communities in freshwater and estuarine ecosystems can be comprised of a wide variety of animals. Some of the groups of animals that are commonly found in the water column of such systems include protozoa (which are single-celled animals), coelenterates (such as jellyfish), and the early life history stages of echinoderms (e.g., starfish), and mollusks (e.g., oysters; Wetzel 1983). In addition, several classes of arthropods are commonly encountered in zooplankton communities, including rotifers, crustaceans (e.g., cladocerans, and copepods), arachnids (i.e., spiders and mites), and insects (such as midges and mayflies which occur in low salinity areas; Wetzel 1983). Finally, the early larval stages of certain fish species are often planktonic; this group of animals is commonly referred to as nekton.

A number of studies have been conducted to evaluate the structure of zooplankton communities within the Calcasieu River/Lake complex. In one of the more recent studies (Vecchione 1987), eleven stations were sampled six times between January, 1984 and February, 1985 to determine seasonal and large-scale spatial patterns of zooplankton distribution. The results of this study indicated that calanoid copepods are the dominant group of organisms in the zooplankton community, with *Acartia tonsa, Prarcalanus crassirostris*, and *Eurytemora affinis* being the most common species. Barnacle larvae and decapods (e.g., shrimp) were also commonly recorded in the zooplankton samples, with *Rhithropanopeus harrisii* being the most abundant decapod species. Penaeid shrimp were commonly observed in these samples (Vecchione 1987).

A companion study was conducted between October, 1983 and August, 1986 to evaluate the structure of nekton communities in the Calcasieu River/Lake complex (Felley 1987a; 1987b). In this study, trawling and seining methods were used to collect monthly nekton samples from Calcasieu Lake and three bayous in the middle and upper portions of the estuary (i.e., Choupique Bayou, Bayou d'Inde, and Contraband Bayou). The results of this study indicated that the nekton community included the early life stages of both fish and invertebrates species. Shrimp and crabs were the most abundant invertebrate species in nekton samples, with some of the commonly encountered species including brown shrimp (*Penaeus aztecus*), white shrimp (*Penaeus setiferus*), shore shrimp *(Palaemonetes intermedius, Palaemonetes pugio,* and *Palaemonetes vulgaris*), freshwater shrimp (*Palaemonetes kadiakensis*), blue crab (*Callinectes sapidus*), gulf crab (*Callinectes similis*), and stone crab (*Menippe mercenaria*). Squid (*Lolliguncula brevis*) and crayfish (*Procambarus* sp.) were also recorded in the nekton samples (Felley 1987b). Among the three bayous that were sampled, Choupique Bayou had the most diverse nekton assemblage and Bayou d'Inde had the least diverse community (Felley 1987b).

6.3.2 Benthic Macroinvertebrate Community

Benthic invertebrates are the animals that live in and on the sediments in freshwater and estuarine ecosystems. Benthic animals are extremely diverse and are represented by nearly all taxonomic groups from protozoa to large invertebrates. The groups of organisms that are commonly associated with benthic communities include protozoa, sponges (i.e., Porifera), coelenterates (such as *Hydra* sp.), flatworms (i.e., Platyhelminthes), bryozoans, aquatic worms (i.e., oligochaetes), crustaceans (such as ostracods, mysids, isopods, decapods, and amphipods), mollusks (such as oysters and clams), and aquatic insects (such as dragonflies, mayflies, stoneflies, true flies, caddisflies, and aquatic beetles). Because benthic invertebrate communities are difficult to study in a comprehensive manner, benthic ecologists often focus on the relatively large members of benthic invertebrate communities, which are known as benthic macroinvertebrates. These organisms are usually operationally defined, for example, as those that are retained on a 0.5 mm sieve.

Benthic invertebrates represent key elements of aquatic food webs because they consume aquatic plants (i.e., such as algae and aquatic macrophytes) and detritus. In this way, these organisms facilitate energy transfer to fish, birds, and other organisms that consume aquatic invertebrates.

There are a number of studies that have been conducted to evaluate the composition of benthic macroinvertebrate communities in the Calcasieu Estuary. For example, Gaston (1987a) collected sediment samples from 28 stations to evaluate the structure of macroinvertebrate communities in the Calcasieu River/Lake complex during 1983 and 1984. The results of this investigation indicated that surface deposit feeders and sub-surface deposit feeders accounted for more than 75% of the total abundance of benthic macroinvertebrates in the upper estuary. The polychaetes, *Streblospio benedicti*, *Hobsonia florida, Laeonereis culveri, Polydora socialis, Nereis succinea, Parandalia fauveli* and *Polydora ligni*, were the most abundant surface deposit feeders in the upper estuary (i.e., from the headwaters to the outlet of Prien Lake). Sub-surface deposit feeders and suspension feeders were also observed in the upper estuary, including oligochaetes (e.g., Tubificidae and Naididae), polychaetes (e.g., *Mediomastus californiensis*), gastropods (e.g., Mactridae; probably *Rangia cuneata*), midges and amphipods (e.g., *Corophium louisianum*; Gaston 1987a; Gaston and Nasci 1988; Gaston *et al.* 1988).

The benthic macroinvertebrate community in the middle portion of the estuary (i.e., from the outlet of Prien Lake to the head of Calcasieu Lake) was similar to that in the upper estuary. However, surface deposit feeders and suspension feeders represented the two main trophic groups in the middle estuary, collectively accounting for more than 70% of the total abundance of macroinvertebrates (Gaston and Nasci 1988). The surface deposit feeders were largely the same as those observed in the upper estuary. The principal suspension feeders included the amphipods, *Corophium louisianum* and *Corophium lacustre*, and *Hargeria rapax* (Tanaidacea). During the summer and fall, sub-surface deposit feeders, primarily oligochaetes (i.e., tubificids) and polychaetes (e.g., *Mediomastus californiensis*), were present at the highest densities (Gaston 1987a; 1987b).

In the lower estuary (i.e., Calcasieu Lake), the benthic invertebrate community was typically dominated by sub-surface deposit feeders, which comprised more than 60% of the total abundance of macroinvertebrates in this area (Gaston and Nasci 1988). The sub-surface deposit feeders in the lower estuary were primarily polychaetes, such as *Mediomastus californiensis* and *Capitella capitata*, and oligochaetes (i.e., tubificids). Surface deposit feeders and suspension feeders comprised the majority of the other benthic macroinvertebrates that were observed in this area; these included polychaetes (*Streblospio benedicti*, *Hobsonia florida, Nereis succinea, Paraprionospio pinnata, Parandalia fauveli,* and *Polydora ligni),* mysids *(Mysidopsis* sp.*),* amphipods (e.g., *Cerapus benthophilis* and *Corophium louisianum*), bivalves (i.e., Mactridae), and *Hargeria rapax* (Tanaidacea). Isopods (*Edotea triloba*) were also observed in the lower estuary (Gaston 1987a; 1987b).

6.4 Fish Community

Fish are key elements of freshwater, estuarine, and marine ecosystems for a number of reasons. As one of the most diverse groups of vertebrates, fish are able to occupy a wide range of ecological niches and habitats (Hoese and Moore 1998). As such, fish represent important components of aquatic food webs by processing energy from aquatic plants (i.e., primary producers), zooplankton and benthic macroinvertebrate species (i.e., primary consumers), or detrivores. Fish represent important prey species for piscivorus (fish-eating) wildlife, including reptiles, birds, and mammals.

A number of studies have been conducted to evaluate fish communities in the Calcasieu Estuary. For example, DeRouen *et al.* (1983) studied marine environments in southwestern Louisiana, including portions of the Calcasieu Estuary. As part of a study of fisheries resources in the vicinity of the Sabine National Wildlife Refuge, Herke *et al.* (1984) evaluated the movement of fish in the southern portion of Calcasieu Lake and associated bayous. Fish communities in the freshwater systems that feed in the upper estuary were evaluated by Felley and Felley (1986). The fish communities in the upper estuary, including the Calcasieu River from the saltwater barrier to Calcasieu Lake, were investigated by Thompson and Fitzhugh (1986). While these historical data sets provided important information on fish communities, their scope and duration limits their application for assessing the status and spatial distributions of fish within the estuary.

In 1983, a more comprehensive investigation was initiated to generate detailed data on the spatial and temporal distributions of fish within the estuary. This study which was conducted between October, 1983 and August, 1986 involved monthly seining and/or trawling at a total of 26 stations throughout the estuary (Felley 1987a; 1987b). During this investigation, over 100 species of fish were recorded in the estuary (Felley 1987b). Using the results of this study, the fish species that utilize habitats within the Calcasieu Estuary can be classified into three main groups, including freshwater species (i.e., species that complete their life histories in oligohaline habitats), estuarine species (i.e., species that complete their entire life history in the estuary), and marine species (i.e., species that are primarily marine, but spend a portion of their life history in the estuary).

There are a variety of freshwater fish species that utilize habitats within the Calcasieu Estuary, particularly in the headwater areas of the various bayous. During the winter and spring, when high rainfall and runoff produce low salinity conditions, freshwater fish species have a wider distribution, in some cases utilizing habitats as far south as Calcasieu Lake. Some of the freshwater species that are commonly observed within the watershed include spotted gar (*Lepisosteus oculatus*), gizzard shad *(Dorosoma cepedianum*), pugnose minnow (*Notropis emiliae*), blacktail shiner (*Notropis venustus*), blue catfish (*Ictalurus furcatus*), channel catfish (*Ictalurus punctatus*), mosquitofish (*Gambusia affinis*), bluegill (*Lepomis macrochirus*), longear sunfish (*Lepomis megalotis*), and white crappie (*Pomoxis annularis*; Felley 1987a; 1987b). Largemouth bass (*Micropterus salmoides*) and chain pickerel (*Esox americanus*) have also been observed within the freshwater portion of the estuary (Felley 1987b).

The truly estuarine fish species utilize habitats in Calcasieu Lake and throughout the estuarine portions of the bayous (Felley 1987a). The commonly observed species that fell within this category included ladyfish (*Elops saurus*), gulf menhaden (*Brevoortia patronus*), sheepshead minnow (*Cyprinodon variegatus*), gulf killifish (*Fundulus grandis*), sailfin molly (*Poecolia latipinna*), inland silverside (*Menidia beryllina*), chain pipefish (*Syngnathus louisianae*), hogchoaker (*Trinectes maculatus*), bay whiff (*Citharichthys spilopterus*), and naked goby *(Gobiosoma bosci;* Felley 1987b).

A variety of marine fish species utilize habitats within the Calcasieu Estuary during a portion of their life history. Some of the species commonly encountered in the estuary include black drum (*Pogonias cromis*), red drum (*Sciaenops ocellatus*), pinfish (*Lagodon rhomboides*), sheepshead (*Archosargus probatocephalus*), sand seatrout (*Cynoscion arenarius*), spotted seatrout *(Cynoscion nebulosus*), silver seatrout (*Cynoscion nothus*), Atlantic croaker (*Micropogonias undulatus*), spot (*Leiostomus xanthurus*), striped mullet (*Mugil cephalus*), white mullet (*Mugil* *curema*), hardhead catfish (*Arius felis*), gafftopsail catfish (*Bagre marinus*), bay anchovy (*Anchoa mitchilli*), and southern flounder (*Paralichthys lethostigma*; Felley 1987a; 1987b). Even such species as tarpon (*Megalops atlanticus*), cobia (*Rachycentron canadum*), Atlantic stingray (*Dasyatis americana*), southern kingfish (*Menticirrhus americanus*), and Atlantic spadefish (*Chaetodipterus faber*) have also been periodically observed within the estuary (Felley 1987b).

6.5 Amphibians

Amphibians are important elements of freshwater components of estuarine ecosystems. The early life history stages of amphibian species are aquatic, feeding primarily on zooplankton to meet their energy requirements. As they mature, most amphibians develop lungs and can utilize both aquatic and terrestrial habitats. Both larval and adult amphibians represent prey species for wildlife species, including fish, reptiles, birds, and mammals.

Only two amphibian species, gulf coast toads (*Bufo valliceps*) and southern leopard frogs (*Rana sphenocephala*), were observed during surveys in the Calcasieu Study area (ChemRisk 1996). The reason for the scarcity of this group of organisms is likely due to the estuarine nature of the area. Amphibians prefer freshwater environments and the brackish conditions found in the study area might prevent amphibians from establishing large populations. As a result, amphibians may have relatively low exposure to COPCs.

6.6 Reptiles

Reptiles represent important components of freshwater and estuarine ecosystems. Reptiles tend to occupy relatively high trophic levels in the food web, in some cases as apex predators (e.g., alligators). In this role, reptiles process energy primarily from fish, birds and small mammals. Certain species and life stages of reptiles also represent important prey items for birds and mammals.

Six species of reptiles have been observed in the Calcasieu Estuary during the Phase I Sampling Program, including the American alligator (*Alligator mississippiensis*), green anole (*Anolis carolinensis*), Texas rat snake (*Elaphe obsoleta lindheimerii*), speckled kingsnake (*Lampropeltis getulus holbrooki*), ground skink (*Scincella lateralis*), and red-eared slider (*Chrysemys scripta elegans*; ChemRisk 2000) Although numerous other reptile species occur regionally, many are more commonly associated with freshwater ecosystems. Reptiles are seldom included as receptors at risk in formal risk assessment processes usually because sufficient toxicological data to evaluate effects are not available (Campbell and Campbell 2000; Meyers-Schöne 2000).

6.7 Birds

Although most birds are primarily terrestrial, many species utilize aquatic and/or riparian habitats through portions or all of their life history. These species consume a variety of aquatic organisms and, hence, are often termed aquatic-dependent wildlife species. Birds and mammals process energy from aquatic plants, invertebrates, fish, amphibians, and reptiles. In turn, these species may be consumed by other avian or mammalian predator species. As such, birds represent critical components of ecological systems.

The land cover and vegetation types in the Calcasieu study area provide a suitable habitat for a large number of bird species. Forty-one species of birds were observed in the study area during a recent biological survey (McLaren/Hart-ChemRisk 1998). Twenty-seven of these species are known to breed in southwestern Louisiana. Most of the recorded species are aquatic or water-dependant birds. Some commonly observed bird species include pied-billed grebe (*Podilymbus podiceps*), anhinga (*Anhinga anhinga*), American white pelican (*Pelecanus erythrorhynchos*), various cormorant species (*Phalacrocorax* sp.), great blue heron (*Ardea herodias*), egrets (e.g., *Egretta* sp.), Canada geese (*Branta canadensis*), ducks (e.g., *Anas* sp.), clapper rail (*Rallus longirostris*), and various gulls (e.g., *Larus* sp.) and terns (e.g., *Sterna* sp.).

The aquatic-dependent birds that occur in the Calcasieu Estuary can be classified into four groups, based on their foraging behavior, including insectivorous birds, sediment-probing birds, carnivorous wading birds, and piscivorus birds. Insectivorous birds, such as cliff swallows (*Petrochelidon pyrrhonota*) and purple martins (*Progne subis*), feed primarily on emergent insects in the vicinity of aquatic habitats. Sediment-probing birds, such as willet (*Cataptrophorus semipalmatus*), the spotted sandpiper (*Actitis macularia*), the black-necked stilt (*Himantopus mexicanus*), the roseate spoonbill (*Ajaia ajaja*) and the lesser scaup (*Aythya affinis*), feed primarily on benthic invertebrates. Carnivorous wading birds, such as the great blue heron and great egret (*Casmerodius albus*) feed on a variety of aquatic organisms, including fish, invertebrates (e.g., crabs), amphibians, and reptiles. Finally, piscivorus birds, such as the belted kingfisher (*Ceryle alcyon*), the osprey (*Pandion haliaetus*), the brown pelican (*Pelecanus occidentalis*) and various species of terns (e.g., *Sterna* sp., *Thalasseus* sp., *Hydroprogne caspia*) feed primarily on fish. Some of these birds have been designated as threatened or endangered species (*Table 6.1*), including the roseate spoonbill, osprey, brown pelican, and glossy ibis.

The preferred habitats for these birds are along freshwater and saltwater environments such as lakes, marshes, lagoons, mud flats, bays and ponds.

6.8 Mammals

Like birds, mammals play an important role in the Calcasieu Estuary area food web, both as prey (e.g., rabbit, *Sylvilagus* sp.) and predators (e.g., river otter, *Lutra canadensis*). They are numerically less dominant than birds in the Calcasieu Estuary area, but nevertheless represent important components of aquatic and riparian ecosystems.

Thorough observations of the study area led to the identification of eight mammalian species including bats (Order Chiroptera), rabbit, raccoon (*Procyon lotor*), eastern fox squirrel (*Sciurus niger*), nutria (*Myocastor coypus*), river otter, white-tailed deer (*Odocoileus virginianus*), and dolphins (Delphinidae; McLaren/Hart-ChemRisk 1998).

The number of mammalian species that feed on aquatic prey and have the potential to occur in the study area is quite limited. Raccoons consume a wide variety of foods including benthic invertebrates and are commonly observed in the study area. Mammalian species that are primarily piscivorus include river otter and American mink (*Mustela vison*). While mink have not been observed in the study area, they still might be present. This is because mink are secretive and visually hard to spot (Gottschang 1981). Moreover, the upstream portions of the study area contains suitable riparian cover habitat that mink prefer (Allen 1986).

Dolphins, mink, river otters and raccoon represent the primary receptors potentially at risk in the Calcasieu Estuary. Mink are top trophic level carnivores that feed mostly on fish, small mammals, birds, eggs, frogs, and macroinvertebrates. Mink have been shown to be a sensitive receptor to some chemicals (Bleavins *et al.* 1984; Rush *et al.* 1983). Raccoons are omnivorous and may consume aquatic invertebrates and fish as parts of their diet, depending on availability. The diet of river otters consists primarily of fish, although they are known to be opportunistic and will feed on a variety of prey, including aquatic insects, amphibians, mammals, birds, and turtles. Otters may probe the bottoms of ponds or streams for invertebrates and, thus, ingest sediment and/or debris in the process. Dolphins are opportunistic feeders, eating a wide variety of fish and invertebrates including eel, fish, squid, and octopus. They are commonly seen in bays, estuaries, harbors, lagoons, river mouths, and ship channels, although they are relatively rare in the Calcasieu study area.

6.9 Rare, Threatened and Endangered Species

Threatened and endangered species are receptors that require special consideration in the Calcasieu Estuary BERA. Endangered species are at risk of becoming extinct throughout all or a significant portion of their range; threatened species are likely to become endangered in the foreseeable future (USFWS 2001a). The current status of these species indicates that they may be more vulnerable than other species to the presence of contaminants and/or other stressors.

The United States Endangered Species Act enacted in 1973, provides federal legislative authority to list a species as threatened or endangered. The purpose of the Act is to 'protect these endangered and threatened species and to provide a means to conserve the ecosystems' of which they are a part (USFWS 2001a). The USFWS has the responsibility to administer the law for terrestrial and freshwater organisms. The State of Louisiana has also enacted endangered species legislation (i.e., Louisiana Endangered Species Act; Sections 1901 to 1907 of Article 56 of the Louisiana Revised Statutes; InfoLouisiana 2001). The Louisiana Department of Wildlife and Fisheries has had the responsibility of administering this law since 1974 (LDWF 2001). These federal and state agencies have developed mechanisms to facilitate cooperation in their efforts to protect threatened and endangered species in the State of Louisiana.

The species that have been listed as threatened or endangered under state and federal legislative authority are shown in *Table 6.1*. Based on the information provided by the USFWS, the only threatened, endangered, or candidate species that exists in the

Calcasieu Estuary is the American bald eagle (*Haliaeetus leucocephalus*; Watson 2001). However, brown pelicans have also been observed within the study area (J. Meyer, USEPA; P. Conzelmann, United States Parks Service. Personal communication). While the American alligator was designated as fully recovered in 1987 and Louisiana populations currently support a regulated annual harvest, it is included in *Table 6.1* because it is classified as "Threatened due to Similarity" (i.e., due to similarity in appearance to several threatened or endangered crocodile and caiman species). A number of other species of fish, reptiles, birds, and mammals that may occur in the estuary have been identified as threatened or endangered by LDWF (2001; Conant and Collins 1998; Dundee and Rossman 1996; LDEC 1931; Robbins *et al.* 1983; Louisiana Ornithological Society, Inc. 2001; Choate *et al.* 1994; Lowery 1974). Federal and state listings for aquatic invertebrates and aquatic plants did not include any species that occur or are expected to occur within the study area.

Chapter 7 Overview of Conceptual Site Model

7.0 Introduction

In accordance with USEPA guidance, the problem formulation for a BERA is intended to provide three main products, including: assessment endpoints, conceptual models, and a risk analysis plan (USEPA 1997a; 1998a). The conceptual model represents a particularly important component of the problem formulation because it enhances the level of understanding regarding the relationships between human activities and ecological receptors at the site under consideration. Specifically, the conceptual model describes key relationships between stressors and assessment endpoints. In so doing, the conceptual model provides a framework for predicting effects on ecological receptors and a template for generating risk questions and testable hypotheses (USEPA 1997a; 1998a). The conceptual model also provides a means of highlighting what is known and what is not known about a site. In this way, the conceptual model provides a basis for identifying data gaps and designing monitoring programs to acquire the information necessary to complete the assessment.

Conceptual models consist of two main elements, including: a set of hypotheses that describe predicted relationships between stressors, exposures, and assessment endpoint responses (along with a rationale for their selection); and, diagrams that illustrate the relationships presented in the risk hypotheses. The following sections of this chapter summarize information on the sources and releases of COPCs, the fate and transport of these substances, the pathways by which ecological receptors are exposed to the COPCs, and the potential effects of these substances on the ecological receptors that occur in the Calcasieu Estuary. In turn, this information is used to develop a series of hypotheses that provide predictions regarding how ecological receptors will be exposed to and respond to the COPCs.

7.1 Sources and Releases of Contaminants of Potential Concern

There are a number of natural and anthropogenic sources of toxic and bioaccumulative substances in the Calcasieu Estuary. Anthropogenic sources of environmental contaminants in the estuary include industrial wastewater discharges, municipal wastewater treatment plant discharges, stormwater discharges, surface water recharge by contaminated groundwater, non-point source discharges, spills associated with production and transport activities, and deposition of substances that were originally released into the atmosphere. A summary of the available information on the sources of environmental contaminants in the Calcasieu Estuary is presented Chapter 3.

Based on the information contained in the SERA, a wide variety of substances have been released into surface waters in the estuary (CDM 1999; *Table 3.1*). Using information on the environmental fate and transport of these substances, participants at the BERA workshop concluded that metals (Cu, Cr, Pb, Hg, Ni, and Zn), PAHs, PCBs, PCDDs/PCDFs, chlorinated benzenes (HCB and HCBD), phthalates (BEHP), carbon disulfide, acetone, unionized ammonia, hydrogen sulfide, and organochlorine pesticides (aldrin and dieldrin) were the principal COPCs in the Calcasieu Estuary (MacDonald *et al.* 2000a; Chapter 3).

7.2 Environmental Fate of Contaminants of Concern

Upon release into aquatic ecosystems, the COPCs partition into environmental media (i.e., water, sediment, and/or biota) in accordance with their physical and chemical properties and the characteristics of the receiving water body. As a result of such partitioning, elevated levels of COPCs can occur in surface water (including the surface microlayer), bottom sediments, and/or the tissues of aquatic organisms. Participants at the recent BERA workshop used the available information on environmental fate to classify the COPCs into four groups, including bioaccumulative substances (i.e., substances that accumulate in the tissues of aquatic organisms), toxic substances that partition into sediments, toxic substances that partition into surface waters, and toxic substances that partition into the surface microlayer (*Table 5.1*; MacDonald *et al.* 2000a). Detailed information on the environmental fate of the COPCs in the Calcasieu Estuary is provided in Appendices 2 to 17 and summarized in Chapter 4.

7.3 Potential Exposure Pathways

Once released to the environment, there are three pathways through which ecological receptors can be exposed to COPCs. These routes of exposure include direct contact with contaminated environmental media, ingestion of contaminated environmental media, and inhalation of contaminated air. For bioaccumulative substances, the ingestion of contaminated prey species represents the most important route of exposure for the majority of aquatic organisms and aquatic-dependent wildlife species. Direct contact with contaminated water and/or contaminated sediment and ingestion of contaminated sediment also represent an important exposure route for many aquatic organisms (*Table 5.2 and 5.3*).

For toxic substances that partition into sediments, direct contact with contaminated sediments and porewater) represents the most important route of exposure for exposure for most aquatic organisms. However, ingestion of contaminated sediments can also represent an important exposure pathway for certain aquatic organisms (e.g., polychaetes that process sediments to obtain food) and aquatic-dependent wildlife species (e.g., sediment-probing birds, such as roseate spoonbills).

For toxic substances that partition into surface water, direct contact with contaminated water represents the most important route of exposure for aquatic organisms (i.e., uptake through the gills and/or through the skin). For aquatic-dependent wildlife species, ingestion of contaminated water represents the principal route of exposure to toxic substances that partition into surface water.

For toxic substances that partition into the surface microlayer, direct contact with the contaminated surface microlayer represents the most important route of exposure for aquatic organisms (i.e., uptake through the gills and/or through the skin). However, aquatic-dependent wildlife species can be exposed to substances that volatilize from the surface microlayer through inhalation. This route of exposure could become important during and following accidental spills when such substances are present as slicks on the water surface. A more detailed description of the pathways through which ecological receptors can be exposed to environmental contaminants is presented in Chapter 5.

7.4 Ecological Receptors at Risk in the Calcasieu Estuary

There are a wide variety of ecological receptors that could be exposed to contaminated environmental media in the Calcasieu Estuary. The aquatic species that occur in the estuary can be classified into six main groups, including microbiota (e.g., bacteria, fungi and protozoa), aquatic plants (including phytoplankton, periphyton, and aquatic macrophytes), aquatic invertebrates (including zooplankton and benthic invertebrates), fish, amphibians, and reptiles. Bird and mammals represent the principal aquatic-dependent wildlife species that occur in the Calcasieu Estuary. *Figure 7.1* presents an example of a gulf coast estuarine food web which illustrates the exposure pathways for the groups of organisms that occupy various trophic levels and the linkages between groups at various trophic levels in the food web. Refinement of this food web model to reflect the receptors that occur in the Calcasieu Estuary and key linkages between groups at various trophic levels (*Figure 7.2*) provides a basis for identifying ecological receptors at risk in the study area.

The COPCs in the Calcasieu Estuary were classified into four categories based on their predicted environmental fate (MacDonald *et al.* 2000a). By considering this information, in conjunction with the exposure pathways that apply to these groups of COPCs, it is possible to identify the receptors that are potentially at risk due to exposure to contaminated environmental media. For bioaccumulative substances, the groups of aquatic organisms that are most likely to be exposed to tissue-associated contaminants include benthic invertebrates, carnivorous fish, amphibians, and reptiles. The groups of aquatic-dependent wildlife species that may be exposed to bioaccumulative substances include insectivorous birds, sediment-probing birds, carnivorous wading birds, piscivorus birds, piscivorus mammals, and omnivorous mammals (*Table 5.3*).

Toxic substances that partition into sediments pose a potential risk to a variety of aquatic organisms and aquatic-dependent wildlife species. The groups of aquatic organisms that are most likely to be exposed to sediment-associated contaminants include decomposers (i.e., microbiota), aquatic plants, benthic invertebrates, benthic fish, and amphibians. Although reptiles can come in contact with contaminated sediments, it is unlikely that significant dermal uptake would occur. Sediment-probing birds are the principal group of aquatic-dependent wildlife species that are exposed to sediment-associated contaminants (*Table 5.3*).

For toxic substances that partition into surface water, aquatic plants, aquatic invertebrates, fish, and amphibians represent the principal groups of exposed aquatic organisms. Although ingestion represents a potential exposure route for both birds and mammals, this pathway is likely to represent a relatively minor source of exposure for aquatic-dependent wildlife species. By comparison, aquatic invertebrates, pelagic fish, and aquatic-dependent birds and mammals (particularly those that wade or float in water) are likely to have the highest potential for exposure to toxic substances that partition into the surface microlayer (*Table 5.3*)

7.5 Hypotheses Regarding the Potential Fate and Effects of Contaminants of Potential Concern in the Calcasieu Estuary

Exposure to environmental contaminants has the potential to adversely affect aquatic organisms and/or aquatic-dependent wildlife species. The nature and severity of such effects are dependent on the substance under consideration, its bioavailability, the characteristics of the exposure medium, the duration of exposure, the species and life stage of the exposed biota, and several other factors. Evaluation of the environmental fate of COPCs and identification of the types of effects that could occur in the various groups of organisms found in the Calcasieu Estuary provides a basis for developing fate and effects hypotheses (*Table 7.1 and 7.2*; which were developed using the information presented in Appendices 2 to 17). In turn, these hypotheses provide a basis for evaluating the logical consequences of exposing ecological receptors to environmental contaminants (i.e., predicting the responses of assessment endpoints when exposed to chemical stressors; USEPA 1998a).

Mercury, PAHs, PCBs, PCDDs/PCDFs, chlorinated benzenes (i.e., HCB and HCBD), and organochlorine pesticides (i.e., aldrin and dieldrin) are the bioaccumulative substances of greatest concern in the Calcasieu Estuary. Short- and long-term exposure to these substances have been demonstrated to adversely affect the survival, growth, and/or reproduction of aquatic invertebrates and fish. The survival, growth, and reproduction of aquatic-dependent birds and mammals are also likely to be adversely affected by many of these substances. Extended exposure to some of these substances can also result in tumor induction and/or immune system suppression (Appendices 2 to 17; Chapter 4). The following fate and effects hypotheses were developed to identify the key stressor-effect relationships that need to be evaluated during the analysis phase of the assessment (*Figure 7.3*):

- Based on the physical-chemical properties (e.g., K_{ow}s) of the bioaccumulative substances of concern, the nature of food web in the Calcasieu Estuary, and the effects that have been documented in laboratory studies, Hg, PCBs, PCDDs/PCDFs, chlorinated benzenes, and organochlorine pesticides that are released into surface waters will accumulate in the tissues of aquatic organisms to levels that will adversely affect the survival, growth, and/or reproduction of benthic invertebrates;

- Based on the physical-chemical properties (e.g., K_{ow}s) of the bioaccumulative substances of concern, the nature of food web in the Calcasieu Estuary, and the effects that have been documented in laboratory studies, Hg, PCBs, PCDDs/PCDFs, chlorinated benzenes, and organochlorine pesticides that are released into surface waters will accumulate in the tissues of aquatic organisms to levels that will adversely affect the survival, growth, and/or reproduction of carnivorous fish;
- Based on the physical-chemical properties (e.g., K_{ow}s) of the bioaccumulative substances of concern, the nature of food web in the Calcasieu Estuary, and the effects that have been documented in laboratory studies, Hg, PCBs, PCDDs/PCDFs, chlorinated benzenes, and organochlorine pesticides that are released into surface waters will accumulate in the tissues of aquatic organisms to levels that will adversely affect the survival, growth, and/or reproduction of amphibians;
- Based on the physical-chemical properties (e.g., K_{ow}s) of the bioaccumulative substances of concern, the nature of food web in the Calcasieu Estuary, and the effects that have been documented in laboratory studies, Hg, PCBs, PCDDs/PCDFs, chlorinated benzenes, and organochlorine pesticides that are released into surface waters will accumulate in the tissues of aquatic organisms to levels that will adversely affect the survival, growth, and/or reproduction of reptiles;
- Based on the physical-chemical properties (e.g., K_{ow}s) of the bioaccumulative substances of concern, the nature of food web in the Calcasieu Estuary, and the effects that have been documented in laboratory studies, Hg, PCBs, PCDDs/PCDFs, chlorinated benzenes, and organochlorine pesticides that are released into surface waters will

accumulate in the tissues of aquatic organisms to levels that will adversely affect the survival, growth, and/or reproduction of insectivorous birds;

- Based on the physical-chemical properties (e.g., K_{ow}s) of the bioaccumulative substances of concern, the nature of food web in the Calcasieu Estuary, and the effects that have been documented in laboratory studies, Hg, PCBs, PCDDs/PCDFs, chlorinated benzenes, and organochlorine pesticides that are released into surface waters will accumulate in the tissues of aquatic organisms to levels that will adversely affect the survival, growth, and/or reproduction of sediment-probing birds;
- Based on the physical-chemical properties (e.g., K_{ow}s) of the bioaccumulative substances of concern, the nature of food web in the Calcasieu Estuary, and the effects that have been documented in laboratory studies, Hg, PCBs, PCDDs/PCDFs, chlorinated benzenes, and organochlorine pesticides that are released into surface waters will accumulate in the tissues of aquatic organisms to levels that will adversely affect the survival, growth, and/or reproduction of carnivorous-wading birds;
- Based on the physical-chemical properties (e.g., K_{ow}s) of the bioaccumulative substances of concern, the nature of food web in the Calcasieu Estuary, and the effects that have been documented in laboratory studies, Hg, PCBs, PCDDs/PCDFs, chlorinated benzenes, and organochlorine pesticides that are released into surface waters will accumulate in the tissues of aquatic organisms to levels that will adversely affect the survival, growth, and/or reproduction of piscivorus birds;
- Based on the physical-chemical properties (e.g., K_{ow}s) of the bioaccumulative substances of concern, the nature of food web in the Calcasieu Estuary, and the effects that have been documented in laboratory studies, Hg, PCBs, PCDDs/PCDFs, chlorinated benzenes, and organochlorine pesticides that are released into surface waters will accumulate in the tissues of aquatic organisms to levels that will adversely

affect the survival, growth, and/or reproduction of omnivorous mammals; and,

- Based on the physical-chemical properties (e.g., K_{ow}s) of the bioaccumulative substances of concern, the nature of food web in the Calcasieu Estuary, and the effects that have been documented in laboratory studies, Hg, PCBs, PCDDs/PCDFs, chlorinated benzenes, and organochlorine pesticides that are released into surface waters will accumulate in the tissues of aquatic organisms to levels that will adversely affect the survival, growth, and/or reproduction of piscivorus mammals.

Many of the COPCs in the Calcasieu Estuary were classified as toxic substances that partition into sediments. These include metals (Cu, Cr, Pb, Hg, Ni, and Zn), PAHs, PCBs, chlorinated benzenes (i.e., HCB and HCBD), phthalates (BEHP), organochlorine pesticides (i.e., aldrin and dieldrin), carbon disulfide, acetone, unionized ammonia, and hydrogen sulfide. Adverse effects on the survival, growth, and/or reproduction have been observed in aquatic plants, aquatic invertebrates, and fish exposed to one or more of these substances in sediments (Appendices 2 to 17; Chapter 4). As these substances have also been shown to be toxic to a variety of avian and mammalian species, exposure to contaminated sediment could adversely affect these receptors. Exposure to sediment-associated contaminants also has the potential to adversely affect the microbial community (i.e., decomposers). The following fate and effect hypotheses were developed to identify the key stressor-effect relationships that need to be evaluated during the analysis phase of the assessment (*Figure 7.4*):

- Based on the environmental fate of the toxic substances that partition into sediments and the effects that have been documented in laboratory studies, metals (Cu, Cr, Pb, Hg, Ni, and Zn), PAHs, PCBs, chlorinated benzenes (i.e., HCB and HCBD), phthalates (BEHP), organochlorine pesticides (i.e., aldrin and dieldrin), carbon disulfide, acetone, unionized ammonia, and hydrogen sulfide will accumulate in whole sediments and/or porewater to levels that will adversely affect the activity of the microbial community (e.g., reduce the rate of carbon processing by decomposers);

- Based on the environmental fate of the toxic substances that partition into sediments and the effects that have been documented in laboratory studies, metals (Cu, Cr, Pb, Hg, Ni, and Zn), PAHs, PCBs, chlorinated benzenes (i.e., HCB and HCBD), phthalates (BEHP), organochlorine pesticides (i.e., aldrin and dieldrin), carbon disulfide, acetone, unionized ammonia, and hydrogen sulfide will accumulate in whole sediments and/or porewater to levels that will adversely affect the survival, growth, and/or reproduction of benthic invertebrates;
- Based on the environmental fate of the toxic substances that partition into sediments and the effects that have been documented in laboratory studies, metals (Cu, Cr, Pb, Hg, Ni, and Zn), PAHs, PCBs, chlorinated benzenes (i.e., HCB and HCBD), phthalates (BEHP), organochlorine pesticides (i.e., aldrin and dieldrin), carbon disulfide, acetone, unionized ammonia, and hydrogen sulfide will accumulate in whole sediments and/or porewater to levels that will adversely affect the survival, growth, and/or reproduction of benthic fish;
- Based on the environmental fate of the toxic substances that partition into sediments and the effects that have been documented in laboratory studies, metals (Cu, Cr, Pb, Hg, Ni, and Zn), PAHs, PCBs, chlorinated benzenes (i.e., HCB and HCBD), phthalates (BEHP), organochlorine pesticides (i.e., aldrin and dieldrin), carbon disulfide, acetone, unionized ammonia, and hydrogen sulfide will accumulate in whole sediments and/or porewater to levels that will adversely affect the survival, growth, and/or reproduction of amphibians;
- Based on the environmental fate of the toxic substances that partition into sediments and the effects that have been documented in laboratory studies, metals (Cu, Cr, Pb, Hg, Ni, and Zn), PAHs, PCBs, chlorinated benzenes (i.e., HCB and HCBD), phthalates (BEHP), organochlorine pesticides (i.e., aldrin and dieldrin), carbon disulfide, acetone, unionized ammonia,

and hydrogen sulfide will accumulate in whole sediments and/or porewater to levels that will adversely affect the survival, growth, and/or reproduction of reptiles; and,

- Based on the environmental fate of the toxic substances that partition into sediments and the effects that have been documented in laboratory studies, metals (Cu, Cr, Pb, Hg, Ni, and Zn), PAHs, PCBs, chlorinated benzenes (i.e., HCB and HCBD), phthalates (BEHP), organochlorine pesticides (i.e., aldrin and dieldrin), carbon disulfide, acetone, unionized ammonia, and hydrogen sulfide will accumulate in whole sediments and/or porewater to levels that will adversely affect the survival, growth, and/or reproduction of sediment-probing birds.

The toxic substances of greatest concern (i.e., COPCs) that partition into water in the Calcasieu Estuary include metals (Cu and Hg) and chlorinated ethanes (TCA and DCE). Adverse effects on survival, growth, and/or reproduction have been observed in aquatic plants, aquatic invertebrates, and fish exposed to one or more of these substances in water (Appendices 2 to 17; Chapter 4). As these substances have also been shown to be toxic to a variety of avian and mammalian species, it is possible that exposure to contaminated water could adversely affect these receptors. However, exposure to these substances through ingestion of contaminated water is likely to be minor. The following fate and effect hypotheses were developed to identify the key stressor-effect relationships that need to be evaluated during the analysis phase of the assessment (*Figure 7.5*):

- Based on the environmental fate of the toxic substances that partition into water and the effects that have been documented in laboratory studies, metals (Cu and Hg) and chlorinated ethanes (TCA and DCE) will accumulate in surface water to levels that will adversely affect the survival, growth, and/or reproduction of aquatic plants;
- Based on the environmental fate of the toxic substances that partition into water and the effects that have been documented in laboratory studies,

metals (Cu and Hg) and chlorinated ethanes (TCA and DCE) will accumulate in surface water to levels that will adversely affect the survival, growth, and/or reproduction of aquatic invertebrates;

- Based on the environmental fate of the toxic substances that partition into water and the effects that have been documented in laboratory studies, metals (Cu and Hg) and chlorinated ethanes (TCA and DCE) will accumulate in surface water to levels that will adversely affect the survival, growth, and/or reproduction of fish; and,
- Based on the environmental fate of the toxic substances that partition into water and the effects that have been documented in laboratory studies, metals (Cu and Hg) and chlorinated ethanes (TCA and DCE) will accumulate in surface water to levels that will adversely affect the survival, growth, and/or reproduction of amphibians.

The toxic substances of greatest concern (i.e., COPCs) that partition into the surface microlayer in the Calcasieu Estuary include metals, VOCs, and SVOCs. Adverse effects on survival, growth, and/or reproduction have been observed in aquatic plants, aquatic invertebrates, and fish exposed to one or more of these substances in water (Appendices 2 to 17; Chapter 4). As these substances have also been shown to be toxic to a variety of avian and mammalian species, it is possible that exposure to contaminated water (i.e., surface microlayer) could adversely affect these receptors. For these receptors, the primary route of exposure would be ingestion. The following fate and effect hypotheses were developed to identify the key stressor-effect relationships that need to be evaluated during the analysis phase of the assessment (*Figure 7.6*):

- Based on the environmental fate of the toxic substances that partition into the surface microlayer and the effects that have been documented in laboratory studies, metals, VOCs, and SVOCs will accumulate in the surface microlayer to levels that will adversely affect the survival, growth, and/or reproduction of aquatic invertebrates;

- Based on the environmental fate of the toxic substances that partition into the surface microlayer and the effects that have been documented in laboratory studies, metals, VOCs, and SVOCs will accumulate in the surface microlayer to levels that will adversely affect the survival, growth, and/or reproduction of pelagic fish;
- Based on the environmental fate of the toxic substances that partition into the surface microlayer and the effects that have been documented in laboratory studies, metals, VOCs, and SVOCs will accumulate in the surface microlayer to levels that will adversely affect the survival, growth, and/or reproduction of aquatic-dependent birds; and,
- Based on the environmental fate of the toxic substances that partition into the surface microlayer and the effects that have been documented in laboratory studies, metals, VOCs, and SVOCs will accumulate in the surface microlayer to levels that will adversely affect the survival, growth, and/or reproduction of aquatic-dependent mammals.

A representation of the relationships between all four groups of chemical stressors, the associated exposure pathways, and the receptor groups at risk is presented in *Figure 7.7*.

Chapter 8 Selection of Assessment and Measurement Endpoints for Evaluating Risks to Ecological Receptors in the Calcasieu Estuary

8.0 Introduction

In the environment, a variety of plant and animal species can be exposed to COPCs (these species are referred to as receptors at risk). Each of these receptors may be exposed to a chemical through different exposure routes and have the potential to exhibit different types and severities of effects. While information on the effects of each chemical on each component of the ecosystem would provide comprehensive information for evaluating ecological risks, it is neither practical nor feasible to directly evaluate risks to all of the individual components of the ecosystem that could be adversely affected by environmental contamination at a site (USEPA 1997a). For this reason, risk assessment activities must be focused on the receptors that represent valued ecosystem components (e.g., sportfish species) and on the receptors that support valued ecosystem functions (e.g., carbon processing by the microbial community, which is needed to support healthy fish populations). Of particular interest are those receptors that are most likely to be adversely affected by the presence of environmental contaminants at the site (USEPA 1998a). The Chapter describes the process that was used to select assessment and measurement endpoints for evaluating risks to ecological receptors in the Calcasieu Estuary.

8.1 Considerations for Selecting Assessment Endpoints and Focal Species

An assessment endpoint is an 'explicit expression of the environmental value that is to be protected' (USEPA 1997a). The selection of assessment endpoints is an essential element of the overall ERA process because it provides a means of focusing assessment activities on the key environmental values (e.g., reproduction of sediment-probing birds) that could be adversely affected by exposure to environmental contaminants.

Assessment endpoints must be selected based on the ecosystems, communities, and species that occur, have historically occurred, or could potentially occur at the site (USEPA 1997a). The following factors need to be considered during the selection of assessment endpoints (USEPA 1997a):

- The COPCs that occur in environmental media and their concentrations;
- The mechanisms of toxicity of the COPCs to various groups of organisms;
- The ecologically-relevant receptor groups that are potentially sensitive or highly exposed to the contaminant, based upon their natural history attributes; and,
- The presence of potentially complete exposure pathways.

Thus, the fate, transport, and mechanisms of ecotoxicity for each contaminant or group of contaminants must be considered to determine which receptors are likely to be most at risk. This information must include an understanding of how the adverse effects of the contaminant could be expressed (e.g., eggshell thinning in birds) and how the form of the chemical in the environment could influence its bioavailability and toxicity.

The primary contaminants of concern in the study area were identified in Chapter 3 of this document. Brief overviews of the environmental fate and ecological effects of each of these COPCs were also provided (Chapter 4) to describe what happens to each chemical when it is released into the environment and how adverse effects could be expressed on various ecological receptors. Importantly, the information on fate and transport of these COPCs facilitated identification of the environmental media in which each chemical is most likely to be found at elevated concentrations (i.e., in water, sediment, or biota; Chapter 4). The review of the available toxicological data provided a basis for identifying which groups of ecological receptors are most sensitive to the effects of each substance (Chapter 4). Chapter 5 of this report provided more detailed descriptions of the various exposure pathways, while the ecological receptors that occur within the study area were identified in Chapter 6. Integration of this information provides a means of developing a conceptual model of the site that clearly identifies linkages between contaminant discharges and effects on key ecological receptors (Chapter 7). This conceptual site model and associated information provide the basis for selecting the assessment endpoints that are most relevant for the Calcasieu Estuary BERA.

8.2 Selection of Assessment Endpoints

As part of the preliminary problem formulation, a number of assessment endpoints were considered for use in the Calcasieu Estuary BERA (CDM 2000). The preliminary list of assessment endpoints included:

- Survival and growth of benthic invertebrates;
- Survival, growth, and reproduction of fish;
- Survival and reproduction of invertebrate-eating, sediment-probing birds;

- Survival and reproduction of carnivorous or piscivorus wading birds;
- Survival and reproduction of piscivorus birds; and,
- Survival and reproduction of piscivorus mammals.

The participants in the BERA workshop (convened in Lake Charles, LA on September 6 and 7, 2000) reviewed the preliminary list of assessment endpoints and concluded that it included many of the receptors of potential concern in the study area. However, the list did not include some of the receptors that could, potentially, be adversely affected by environmental contamination (i.e., primary productivity, pelagic invertebrates, amphibians, reptiles, insectivorous birds, omnivorous mammals, and carnivorous mammals). In addition, the assessment endpoints that were identified previously had not been linked directly to the specific chemicals or chemical classes for which they were most applicable. For this reason, workshop participants decided to re-evaluate the candidate assessment endpoints based on the three categories of COPCs that were identified previously (MacDonald *et al.* 2000a).

Workshop participants recognized that routes of exposure and mechanisms of toxicity differ for the various COPCs that occur in the Calcasieu Estuary. For this reason, the COPCs were separated into four groups, based on their mode of action and likely environmental fate. For the first group of COPCs, bioaccumulative substances, a total of ten groups of receptors were identified, including benthic invertebrates, carnivorous fish, reptiles, amphibians, insectivorous birds, sediment-probing birds, carnivorous wading birds, other piscivorus birds, and aquatic-dependent mammals (*Table 8.1*). For each of these groups of receptors, the workshop participants identified assessment endpoints, focal species, and associated measurement endpoints. Likewise, assessment endpoints were identified for the toxic substances that are likely to partition into sediments (*Table 8.2*), the toxic substances that are likely to partition into overlying water (*Table 8.3*), and the substances that are likely to occur in the surface microlayer (*Table 8.4*). The assessment endpoints that are presented in *Tables 8.1 to 8.4* provide a comprehensive suite from which priority assessment endpoints for inclusion in the BERA were selected (see Section 9.1; *Tables 9.1, 9.4, and 9.5*).

8.3 Selection of Measurement Endpoints

A measurement endpoint is defined as 'a measurable ecological characteristic that is related to the valued characteristic that is selected as the assessment endpoint' and it is a measure of biological effects (e.g., mortality, reproduction, growth; USEPA 1997a). Measurement endpoints are frequently numerical expressions of observations (e.g., toxicity test results, community diversity measures) that can be compared to similar observations at a control and/or reference site. Such statistical comparisons provide a basis for evaluating the effects that are associated with exposure to a contaminant or group of contaminants at the site under consideration. Measurement endpoints can include measures of exposure (e.g., contaminant concentrations in water or sediments) or measures of effects (e.g., survival or growth of amphipods in 10-d toxicity tests). The relationship between an assessment endpoint, a risk question, and a measurement endpoint must be clearly described within the conceptual model and must be based on scientific evidence (USEPA 1997a).

After identifying receptors of concern and selecting assessment endpoints, the participants at the BERA workshop described the linkages that are likely to exist between exposure media (i.e., stressors) and receptors within the Calcasieu Estuary. The results of this process enabled workshop participants to identify focal species for each group of receptors and each group of chemical substances. In turn, this information was used to identify measurement endpoints that could be used to evaluate the status of each assessment endpoint (*Table 8.1 to 8.4*). Workshop participants recognized that it would not be practical nor possible to incorporate all of the possible measurement endpoints into the RI. For this reason, the workshop participants identified measurement endpoints that would provide the most useful information for evaluating the ecological risks associated with exposure to environmental contaminants in the study area. Subsequently, this input was compiled and used to identify the highest priority measurement endpoints for inclusion in the RI (i.e., the Phase II sampling program; see *Tables 9.1, 9.4, and 9.5*). Based on the input that was provided by workshop participants, the highest priority for inclusion in the BERA.

Chapter 9 Risk Analysis Plan and Uncertainty Analysis

9.0 Introduction

The development of a risk analysis plan represents the final stage of the problem formulation process. During risk analysis planning, risk questions and testable hypotheses are developed and evaluated to determine how they will be assessed using available and new data (USEPA 1997a). The risk analysis plan includes four components, including descriptions of the assessment design, the data requirements, the measurements that will be made, and the methods for conducting the analysis phase of the risk assessment (USEPA 1997a). Outstanding data gaps and uncertainties associated with the risk assessment are also identified during risk analysis planning.

The risk analysis plan and associated uncertainty analysis for the Calcasieu Estuary BERA are presented in the following sections of this document. The first element of the risk analysis plan (Section 9.1) identifies the assessment endpoints that have been selected for the BERA (including a rationale for their selection), articulates the associated risk questions and testable hypotheses, and describes how the data on each measurement endpoint will be used in the assessment. The second element of the analysis plan (Section 9.2) describes how the various lines of evidence will be used to assess risks relative to the selected assessment endpoints. Finally, the uncertainty analysis (Section 9.3) describes the sources of uncertainty in the assessment and discusses how uncertainties associated with the exposure and effects assessments will be quantified and addressed.

9.1 Assessment Endpoints, Risk Questions, and Measurement Endpoints for the Calcasieu Estuary BERA

Analysis planning is a critical step of the problem formulation process. Importantly, this plan must describe how the data that are collected on the various measurement endpoints will be used to answer key risk questions and evaluate the status of the assessment endpoints. The following sections describe the rationale for selecting target receptor groups and assessment endpoints, the risk questions that need to be answered during the BERA, and the measurement endpoints that were selected to provide the data needed to evaluate the status of the assessment endpoints.

9.1.1 Microbial Communities

Microbial communities, which consist of bacteria, protozoans, and fungi, play several essential roles in estuarine ecosystems. First, microbial communities transform the energy from aquatic organisms into forms that can be used directly by primary consumers, such as small crabs, worms, shellfish, and snails (e.g., by degrading and transforming detrital organic matter, Apple *et al.* 2001). Microbial communities also play a key role in the cycling and transformation of nutrients in sediments and the water column. For example, the microbial community is an essential element of the nitrogen cycle, in which atmospheric nitrogen is converted through a series of steps into nitrates, nitrites, and ammonia. These forms of nitrogen represent essential plant nutrients and are the basic building blocks for protein synthesis. The sulfur cycle in aquatic environments, in which hydrogen sulfide is converted to sulfate (which is incorporated into plant and animal tissues), is also mediated by the microbial community (Odum 1975). The microbial community supports primary productivity by transforming phosphorus into forms that can be readily used by aquatic plants (i.e., phosphate). Finally, carbon cycling (i.e., between the dissolved and particulate forms) in aquatic ecosystems is dependent on the microbial community.

Assessment Endpoint - Activity of the Aquatic Microbial Community: As the microbial community supports a number of critical ecosystem functions (see above), it is important to evaluate the effects of environmental contaminants on this group of ecological receptors. Aquatic microorganisms, including bacteria, protozoans, and fungi, can be exposed to environmental contaminants through direct contact with contaminated surface water, through contact with contaminated sediments, and through contact with contaminated porewater. Of these, exposure to contaminated sediments probably represents the primary route of exposure for epibenthic and infaunal microbial species. For this reason, it is important to evaluate the effects of exposure to contaminated sediments on the activity of the microbial community (i.e., the rate at which microorganisms perform essential ecosystem functions, such as processing organic carbon). The goal of this assessment is to determine if contaminated sediments are likely to adversely affect the key functions that are provided by the microbial community (*Table 9.1*).

Risk Questions/Testable Hypotheses: To support the BERA, the investigations to assess the effects of environmental contaminants on the microbial community should be designed to answer the following risk question:

- Is the metabolic rate of bacteria (i.e., the activity of aquatic microbiota, as indicated by the bioluminescence of the bacterium, *Vibrio fisheri*) exposed to sediments from the Calcasieu Estuary area of concern significantly lower ($P<0.1$) than that for bacteria exposed to reference sediments?

Measurement Endpoints: The results of solid phase sediment toxicity tests with the bacterium, *Vibrio fisheri* [i.e., Microtox®; using the methods described in Johnson (1998) and in Johnson and Long (1998)] will be used to evaluate the effects of contaminated sediments on the activity of the microbial community. More specifically, bioluminescence in the bacterium, *Vibrio fisheri,* will be used as an indicator of microbial metabolic rate and, hence, the ability of the microbial community to deliver key functions (such as carbon processing). Although *Vibrio fisheri* is a marine species, it has been used as a surrogate species for evaluating the effects of contaminants in surface water, porewater, sediments, and elutriates in freshwater and estuarine environments (Johnson 1998; Johnson and Long 1998). In this assessment the EC_{50} bioluminescence of *Vibrio fisheri* (i.e., the concentration of sediment that is added to a sample that results in a 50% reduction in bioluminescence) exposed to Calcasieu Estuary sediments will be compared with that of bacteria exposed to reference sediments from the study area. Sediment samples will be designated as toxic to the microbial community if EC_{50} for bacterial bioluminescence in Calcasieu Estuary sediments is significantly lower ($P<0.1$) than that in reference sediments.

9.1.2 Aquatic Plants

Aquatic plants, including phytoplankton, periphyton, and aquatic macrophytes, are referred to as primary producers because they convert the sun's energy to organic matter. The organic matter produced by aquatic plants represents the primary source of food for many of the animals that reside, either permanently or seasonally, within the watershed. As such, aquatic plants represent fundamental elements of aquatic food webs, providing the organic matter that is consumed by zooplankton, benthic invertebrates, and herbivorous (i.e., plant-eating) fish. Aquatic plants also support diverse microbial communities (i.e., which consist of various types of bacteria), that decompose plant matter and convert it into forms that are more readily usable by other organisms.

Assessment Endpoint - Survival and Growth of Aquatic Plants: Because aquatic plants represent essential components of the aquatic ecosystem and support many critical ecosystem functions (i.e., carbon processing, nutrient cycling, etc.), it is important to evaluate the effects of environmental contaminants on this group of ecological receptors. Aquatic plants can be exposed to environmental contaminants through direct contact with contaminated surface water (i.e., all three groups of plants identified above), through contact with contaminated sediments (i.e., periphyton and macrophytes), and, through contact with contaminated porewater. Although it would be useful to evaluate the effects of environmental contaminants on all three groups of aquatic plants through the various exposure routes, focusing on porewater provides a means of evaluating the exposure scenario that is most likely to adversely affect aquatic plants. If adverse effects are not observed as a result of exposure to porewater from contaminated sediments, then it is unlikely that aquatic plants would be adversely affected through other exposure routes (*Table 9.1*).

Risk Questions/Testable Hypotheses: To support the BERA, the investigations that are undertaken to evaluate the effects of environmental contaminants on aquatic plants should be designed to answer the following risk question:

- Is the survival, growth, or reproduction of aquatic plants (as indicated by germination rate, germling length, and cell number of the algae, *Ulva lactuca*) exposed to porewater from Calcasieu Estuary sediments significantly lower ($P<0.1$) than that for aquatic plants exposed to porewater from reference sediments?

Measurement Endpoints: The results of porewater toxicity tests with the aquatic macrophyte, sea lettuce (*Ulva lactuca*) will be used to evaluate the effects of contaminated porewater on aquatic plants. More specifically, germination rate, germling length, and cell number of sea lettuce (as surrogates for survival and growth of aquatic plants) will be evaluated using the methods described by Hooten and Carr (1998). Although sea lettuce is primarily a marine species, it is considered to be an appropriate surrogate for freshwater and estuarine aquatic plant species (Hooten and Carr 1998). In this assessment, germination rate, germling length, and cell number of sea lettuce in porewater from Calcasieu Estuary sediments will be compared with that of sea lettuce in porewater from reference sediments from the study area. Porewater samples will be designated as toxic to aquatic plants if the germination rate, germling length, or cell number of sea lettuce in porewater from Calcasieu Estuary sediments is significantly lower ($P<0.1$) than that in porewater from reference sediments.

9.1.3 Invertebrate Communities

Invertebrate communities in freshwater and estuarine ecosystems consist primarily of zooplankton and benthic macroinvertebrate communities. Aquatic invertebrates (i.e., primary consumers) represent essential elements of aquatic food webs because they consume aquatic plants (i.e., primary producers) and provide important food sources for fish and many other aquatic organisms. Because most of the contaminants of concern in the study area are expected to partition primarily into sediments, assessment of the effects of sediment-associated contaminants on the survival, growth, and reproduction of benthic invertebrates represents a key element of the aquatic risk assessment.

Assessment Endpoint - Survival, Growth, and Reproduction of Benthic Invertebrates: The benthic invertebrate community represents an essential component of aquatic food webs, providing an important source of food for many species of fish, birds, and mammals. As such, it is important to evaluate the effects of environmental contaminants on this group of ecological receptors. Benthic invertebrates can be exposed to environmental contaminants through direct contact with contaminated surface water, through contact with contaminated sediments, and through contact with contaminated porewater. Of these, exposure to contaminated sediments and porewater probably represent the primary routes of exposure for epibenthic and infaunal invertebrate species. For this reason, it is important to evaluate the effects of exposure to contaminated sediments and porewater on the survival, growth, and reproduction of benthic invertebrates. In this way, it is possible to determine if contaminated sediments and/or porewater are likely to adversely affect the key functions that are provided by the invertebrate community (*Table 9.1*).

Risk Questions/Testable Hypotheses: To support the BERA, the investigations to assess the effects of environmental contaminants on the benthic invertebrate community should be designed to answer several important risk questions, including:

- Are the levels of contaminants in whole sediments from the Calcasieu Estuary greater than the sediment quality benchmarks for the survival, growth, or reproduction of benthic invertebrates?
- Are the levels of contaminants in porewater from Calcasieu Estuary sediments greater than the toxicity thresholds for survival, growth, or reproduction of benthic invertebrates?
- Is the survival of benthic invertebrates (as indicated by the survival of the amphipods *Hyalella azteca* and *Ampelisca abdita*, and the

polychaete *Neries virens*) exposed to whole sediments from the Calcasieu Estuary significantly lower (P<0.1) than that in reference sediments?

- Is the growth of benthic invertebrates (as indicated by the growth of the amphipod, *Hyalella azteca*) exposed to whole sediments from the Calcasieu Estuary significantly lower (P<0.1) than that in reference sediments?
- Is the reproductive success of benthic invertebrates (as indicated by fertilization and embryo development in the sea urchin, *Arbacia punctulata*) exposed to porewater from Calcasieu Estuary sediments significantly lower (P<0.1) than that of benthic invertebrates exposed to porewater from reference sediments?
- Is the structure of benthic macroinvertebrate communities (as indicated by annelid abundance, arthropod abundance, and index of contamination) in Calcasieu Estuary sediments outside the normal range (i.e., 95% CI) for benthic invertebrate communities in reference areas?

Measurement Endpoints: Data on a number of measurement endpoints will be used to determine if sediments are sufficiently contaminated to adversely affect the survival, growth, or reproduction of benthic invertebrates in the Calcasieu Estuary. First, sediment chemistry data will be used to determine if the concentrations of contaminants of potential concern (COPCs) in Calcasieu Estuary sediments are sufficient to cause or substantially contribute to sediment toxicity. More specifically, the measured concentration of each COPC in each sediment sample will be compared to the corresponding effect-based sediment quality guideline for the protection of aquatic life (Long *et al.* 1995; MacDonald *et al.* 1996; MacDonald *et al.* 2000b; *Table 9.2*). In addition, the potential effects of mixtures of sediment-associated contaminants will be evaluated using simple toxic units models that have been validated using data from other sites (Long and MacDonald 1998; USEPA 2000c). Application of these toxic units models will be facilitated by calculating mean sediment quality guidelines quotients (SQG-Qs), including mean ERM-Qs and mean PEC-Qs for each sediment sample using the procedures that were developed by Long and MacDonald (1998) and USEPA (2000c), respectively. The mean SQG-Qs that correspond to a 50% probability of observing significant toxicity to marine or freshwater amphipods (i.e., mean ERM-Qs of 1.0 and mean PEC-Q of 0.7) will be used as toxicity thresholds for assessing whole sediment chemistry data. Sediment samples with mean SQG-Q in excess of one or both of these toxicity thresholds will be considered to have contaminant concentrations sufficient to adversely affect the survival and/or growth of benthic invertebrates. The probability that sediment toxicity will be observed in individual sediment samples will be evaluated using the dose-response models that were developed by USEPA (2000c).

Data on the concentrations of COPCs in porewater will also be used to determine if sediments are sufficiently contaminated to adversely affect the survival, growth, or reproduction of benthic invertebrates in the Calcasieu Estuary. More specifically, the measured concentrations of COPCs in porewater will be compared to the toxicity thresholds that have been established for the survival, growth, and reproduction of invertebrates [e.g., water quality criteria; no observed adverse effect levels (NOAELS); lowest observed adverse effect levels (LOAELs); *Table 9.3*], based on the results of water-only toxicity tests [as reported in the USEPA AQUIRE (Aquatic Toxicity Information Retrieval) database and other published sources; see Appendices 2 to 17]. Porewater samples with concentrations of one or more COPCs in excess of one or more toxicity threshold will be considered to have contaminant concentrations sufficient to adversely affect the survival, growth, and/or reproduction of benthic invertebrates.

The results of solid phase sediment toxicity tests will also be used to evaluate the effects of contaminated sediments on the survival of benthic invertebrates. More specifically, the results of 10-day whole sediment toxicity tests with the infaunal amphipod, *Ampelisca abdita*, will be used to evaluate the effects of contaminated sediments on the survival of benthic invertebrates (ASTM 2000b). In addition, the effects of sediment-associated contaminants on invertebrate survival will be evaluated using the results 10-day and 28-day whole sediment toxicity tests with the epibenthic amphipod, *Hyalella azteca* (ASTM 2000a; USEPA 2000d). Furthermore, the results of 28-day whole sediment exposure tests with the polychaete, *Nereis virens*, will be used to evaluate the effects of sediment-associated contaminants on invertebrate survival (ASTM 2000c). The survival of amphipods and polychaetes exposed to Calcasieu Estuary sediments will be compared with that of amphipods and polychaetes exposed to reference sediments from the study area. Sediment samples will be designated as toxic to the benthic invertebrates if amphipod or polychaete survival in Calcasieu Estuary sediments is significantly lower ($P<0.1$) than that in reference sediments.

The results of solid phase sediment toxicity tests will also be used to evaluate the effects of contaminated sediments on the growth of the benthic invertebrates. More specifically, the effects of sediment-associated contaminants on invertebrate growth will be evaluated using the results 10-day and 28-day whole sediment toxicity tests with the epibenthic amphipod, *Hyalella azteca* (ASTM 2000a; USEPA 2000d). The growth of amphipods exposed to Calcasieu Estuary sediments will be compared with that of amphipods exposed to reference sediments from the study area. Sediment samples will be designated as toxic to the benthic invertebrates if amphipod growth in Calcasieu Estuary sediments is significantly lower ($P<0.1$) than that in reference sediments.

The effects of sediment-associated contaminants on the reproduction of invertebrates will be evaluated using the results of porewater toxicity tests. More specifically, the effects of contaminated sediments on invertebrate reproduction will be evaluated using the results of porewater toxicity tests with the sea urchin, *Arbacia punctulata*, in which fertilization and embryo development are measured. In this context, the sea urchin fertilization and embryo development test will be used as a surrogate for reproductive effects on other invertebrate species (Carr and Chapman 1992; Carr *et al.* 1996a; 1996b; 1997). The fertilization and embryo development of sea urchins exposed to porewater from Calcasieu Estuary sediments will be compared with that of sea urchin gametes and embryos exposed to porewater from reference sediments from the study area. Porewater samples will be designated as toxic to the benthic invertebrates if fertilization or embryo development in porewater from Calcasieu Estuary sediments is significantly lower ($P<0.1$) than that in porewater from reference sediments.

The effects of contaminated sediments on benthic invertebrates will also be evaluated using the results of benthic invertebrate community structure analyses. More specifically, data on three key indicators of benthic invertebrate community structure, including percent annelid abundance, percent arthropod abundance, and index of contamination, will be used to evaluate effects on benthic invertebrate community structure. These metrics were selected because the results of previous studies have shown that they provide effective bases for identifying sediment samples with degraded benthic communities (Gaston and Nasci 1988; Gaston *et al.* 1988; Gaston and Young 1992; Brown *et al.* 2000). To facilitate this assessment, the normal range of these endpoints (i.e., the upper and lower 95% confidence intervals) will be calculated for sediments from the reference sites

(Reynoldson *et al.* 1995). Subsequently, the measured values for each of these metrics for sediment samples from the Calcasieu Estuary will be compared to the normal range of these metrics for the reference sites. For each sediment sample the benthic community will be designated as degraded if one or more of these metrics falls outside the range of normal values for the reference sites.

9.1.4 Fish Communities

Fish represent essential components of aquatic food webs. Importantly, fish process energy from aquatic plants (i.e., primary producers), zooplankton and benthic macroinvertebrate species (i.e., primary consumers), and/or detrivores and convert that energy to biomass. As they represent important prey species for piscivorus (fish-eating) wildlife, including reptiles, birds, and mammals, fish play a key role in transferring processed energy through the food web.

Assessment Endpoint - Survival, Growth, and Reproduction of Benthic and Pelagic Fish: The fish community represents an essential component of aquatic food webs because it provides an important source of food for many species of birds and mammals. Herbivorous, planktivorous, and omnivorous fish at lower trophic levels in aquatic food webs (i.e., those species that consume aquatic plants, planktonic invertebrates, and/or benthic invertebrates) also represent important prey species for carnivorous fish species, including both benthic and pelagic fish species. As such, it is important to evaluate the effects of environmental contaminants on this group of ecological receptors.

Benthic and pelagic fish species can be exposed to environmental contaminants through several exposure routes, including contact with contaminated surface water (i.e., for benthic and pelagic species), contact with contaminated sediments (i.e., for benthic species), and/or contact with contaminated porewater (i.e., for those species that burrow into the sediments or spawn in or on the bottom substrates). In addition, consumption of contaminated prey organisms represents an important exposure route for those species that consume infaunal invertebrate or forage fish species. For this reason, it is important to evaluate the effects of contaminated surface water, porewater, and sediments on the survival, growth, and reproduction of fish (*Table 9.4*).

Risk Questions/Testable Hypotheses: To support the BERA, the investigations to assess the effects of environmental contaminants on fish should be designed to answer several key risk questions, including:

- Are the concentrations of contaminants in overlying water from the Calcasieu Estuary greater than the toxicity thresholds for the survival, growth, and reproduction of benthic or pelagic fish?
- Are the concentrations of contaminants in porewater water from Calcasieu Estuary sediment greater than the toxicity thresholds for the survival, growth, and reproduction of fish?
- Is the survival of fish (as indicated by egg and embryo survival in the red drum, *Sciaenops oscellatus*) exposed to porewater from Calcasieu Estuary sediments significantly lower ($P<0.1$) than that in fish exposed to porewater from reference sediments?
- Is the reproductive success of fish (as indicated by hatching success in the red drum, *Sciaenops oscellatus*) exposed to porewater from Calcasieu Estuary sediments significantly lower ($P<0.1$) than that in fish exposed to porewater from reference sediments?

Measurement Endpoints: Data on a number of measurement endpoints will be used to determine if contaminated surface water, porewater, or sediments are adversely affecting the survival, growth, or reproduction of fish in the Calcasieu Estuary. First, surface water chemistry data will be used to determine if the concentrations of COPCs in surface water from the Calcasieu Estuary are sufficient to cause or substantially contribute to toxicity to fish. More specifically, the measured concentrations of COPCs in surface water will be compared to the toxicity thresholds that have been established for the survival, growth, and reproduction of fish (e.g., water quality criteria; NOAELS; LOAELs; *Table 9.3*), based on the results of water-only toxicity tests (as reported in the USEPA AQUIRE database and other published sources; see Appendices 2 to 17). Surface water samples with concentrations of one or more COPCs in excess of one or more toxicity thresholds will be considered to have contaminant concentrations sufficient to adversely affect the survival, growth, or reproduction of fish.

Data on the concentrations of COPCs in porewater will be used to determine if contaminated sediments are adversely affecting the survival, growth, or reproduction of fish in the Calcasieu Estuary. More specifically, the measured concentrations of COPCs in porewater will be compared to the toxicity thresholds that have been established for the survival, growth, and reproduction of fish (e.g., water quality criteria; NOAELS; LOAELs; *Table 9.3*), based on the results of water-only toxicity tests (as reported in the USEPA AQUIRE database and other published sources; Appendices 2 to 17). Porewater samples with concentrations of one or more COPCs in excess of one or more toxicity thresholds will be considered to have contaminant concentrations sufficient to adversely affect the survival, growth, or reproduction of fish.

The effects of sediment-associated contaminants on the survival and reproduction of fish will be evaluated using the results of porewater toxicity tests. More specifically, the effects of contaminated sediments on fish survival and reproduction will be evaluated using the results of porewater toxicity tests with the red drum, *Sciaenops ocellatus*, in which egg hatching success and larval survival are measured [i.e., using the methods that were developed by Carr and Chapman (1992)]. In this context, red drum egg hatching success and larval survival will be used as surrogates for survival and reproductive effects, respectively, on other fish species that spawn in the estuary. In this assessment, the hatching success of red drum eggs and survival of larvae exposed to porewater from Calcasieu Estuary sediments will be compared with that for red drum eggs and larvae exposed to porewater from reference sediments from the study area. Porewater samples will be designated as toxic to fish if hatching success of red drum eggs and survival of larvae in porewater from Calcasieu Estuary sediments is significantly lower ($P<0.1$) than that in porewater from reference sediments.

9.1.5 Avian Communities

There are numerous bird species that depend on the Calcasieu Estuary for food and habitat. Some of these species are rare, threatened, or endangered, but occur in large numbers in the estuary (e.g., brown pelican). Aquatic-dependent bird species represent important elements of aquatic food webs because they process energy from zooplankton, benthic macroinvertebrates, fish, amphibians, and reptiles. In turn, birds represent a source of food for other wildlife species, such as reptiles, other birds, or mammals.

Assessment Endpoint - Survival and Reproduction of Aquatic-Dependent Bird Species. Bird species that depend on the aquatic system for food and habitat (i.e., aquatic-dependent bird species) can be classified, based on their feeding habits, into four main groups: insectivorous birds (i.e., species that eat insects), sediment-probing birds (i.e., species that eat benthic macroinvertebrates), carnivorous wading birds (i.e., species that eat various types of aquatic organisms, including invertebrates, small fish, reptiles and amphibians) and piscivorus birds (i.e., species that eat primarily fish).

Although these ecological receptors can be exposed to environmental contaminants through dermal contact with contaminated surface water or sediments (i.e., dermal exposure) or consumption of contaminated surface water or sediment (i.e., incidental ingestion), the bulk of their exposure is associated with the consumption of contaminated prey items. This is particularly true for persistent and bioaccumulative COPCs (e.g., PCBs, mercury) that biomagnify up the food chain. Therefore, it is important to evaluate the effects of contaminated prey items on the survival and reproduction of birds. Because insectivorous birds (such as purple martins) are likely to utilize habitats in the vicinity of freshwater sources (i.e., where emergent insects, such as midges, are more likely to occur), they were not included as focal species for this assessment (*Table 9.5*).

Risk Questions/Testable Hypotheses. To support the BERA, the assessment of the risks of environmental contaminants on birds should be designed to answer several key risk questions, including:

- Does the dose of contaminants received by sediment-probing birds from consumption of the tissues of prey species and from other media in the Calcasieu Estuary (e.g., sediment) exceed the toxicity reference values (TRVs) for survival or reproduction of birds? If yes, what are the probabilities of effects of differing magnitude for survival and/or reproduction of sediment-probing birds?

- Does the dose of contaminants received by carnivorous wading birds from consumption of the tissues of prey species and from other media in the Calcasieu Estuary (e.g., sediment) exceed the toxicity reference values (TRVs) for survival or reproduction of birds? If yes, what are the probabilities of effects of differing magnitude for survival and/or reproduction of carnivorous wading birds?
- Does the dose of contaminants received by piscivorus birds from consumption of the tissues of prey species and from other media in the Calcasieu Estuary (e.g., sediment) exceed the toxicity reference values (TRVs) for survival or reproduction of birds? If yes, what are the probabilities of effects of differing magnitude for survival and/or reproduction of piscivorus birds?

Measurement Endpoints. A number of measurement endpoints will be used to evaluate risks to aquatic dependent birds associated with the consumption of contaminated prey items and other contaminated media. First, the potential for adverse effects on sediment-probing birds (e.g., willet, spotted sandpipers, and roseate spoonbills) will be evaluated using tissue chemistry data from prey species and foraging information for the sediment-probing bird species of interest. Specifically, the dose received by selected sediment-probing bird species will be estimated by multiplying food ingestion rates (normalized to body weight) by the concentrations of contaminants that accumulated in the tissues of the polychaete, *Nereis virens*, during 28-day bioaccumulation tests (i.e., conducted using sediments from the Calcasieu Estuary and grouped using information on the foraging range of each species). Where appropriate, the estimated doses will also incorporate intake from other media (e.g., sediment). At this stage of the analysis, doses will be estimated using conservative inputs (e.g., upper percentiles for concentrations in prey tissues) and assumptions (e.g., assume 100% of diet is from the Calcasieu estuary). The estimated doses will then be compared to appropriate toxicity reference values for the survival and reproduction of birds (i.e., NOAELS and LOAELs; *Table 9.6*; Appendices 2 to 17). In this evaluation, the tissue residue data for polychaetes will be used to approximate the concentrations of contaminants in the tissues of sediment-dwelling organisms (i.e., benthic macroinvertebrates) in different areas of the Calcasieu Estuary. Sediment-probing birds receiving doses of one or more COPCs in excess of one or more TRVs will be considered to be potentially at risk. This comparison will be done at a number of locations within the Calcasieu estuary and at several reference locations.

For those locations and COPCs for which doses exceed TRVs for sediment-probing birds, additional exposure, effects and risk analyses will be undertaken to better understand the nature and severity of the risks posed. In these analyses, the conservative inputs in the exposure models will be replaced by distributions of the available data. The distributions will represent our state of knowledge regarding variability of each input parameter (e.g., spatial variability of prey tissue concentrations over the foraging range of sediment-probing bird species of interest). For the effects analyses, dose-response relationships will be used rather than TRVs, where possible. The resulting exposure and effects distributions can be integrated to produce risk curves that show the relationship between probability and magnitude of effect (see Section 9.2 for an overview of the planned analyses).

The potential for adverse effects on carnivorous wading birds, such as great egret and great blue heron, will be evaluated using a similar approach to that described for sediment-probing birds. Specifically, the data on the concentrations of contaminants measured in invertebrates, small fish (i.e., <15 cm in length), and medium-sized fish (i.e., 15 to 30 cm) will be used in conjunction with ingestion rate information to estimate dose received. The tissue data will be compiled by geographic area within the estuary (based on the diet and foraging range of each bird species) and compared to appropriate toxicity reference values for survival and reproduction of birds (i.e., NOAELS and LOAELs; *Table 9.6*; Appendices 2 to 17). In this evaluation, the tissue residue data for invertebrates (e.g., shrimp and polychaetes) and fish collected in the estuary will be extrapolated to other organisms that are consumed by carnivorous wading birds (e.g., fidler crabs, juvenile blue crabs), but for which data are unavailable. To the extent possible, the extrapolation will involve selecting data from measured prey species that have similar trophic levels and exposure routes as those prey species for which data are unavailable. Where appropriate, the estimated doses will also incorporate intake from other media (e.g., sediment). At this stage of the analysis, doses will be estimated using conservative inputs (e.g., upper percentiles for concentrations in prey tissues) and assumptions (e.g., assume 100% of diet is from the Calcasieu estuary). Carnivorous wading birds receiving doses of one or more COPCs in excess of one or more TRVs will be considered to be potentially at risk. This comparison will be done at a number of locations within the Calcasieu estuary and at several reference locations.

For those locations and COPCs for which doses exceed TRVs for carnivorous wading birds, additional exposure, effects and risk analyses will be undertaken to better understand the nature and severity of the risks posed. In these analyses, the conservative inputs in the exposure models will be replaced by distributions of the available data. The distributions will represent our state of knowledge regarding variability of each input parameter (e.g., spatial variability of prey tissue concentrations over the foraging range of carnivorous wading bird species of interest). For the effects analyses, dose-response relationships will be used rather than TRVs where possible. The resulting exposure and effects distributions can be integrated to produce risk curves that show the relationship between probability and magnitude of effect (see Section 9.2 for an overview of the planned analyses).

The potential for adverse effects on piscivorus birds, such as osprey, belted kingfisher, and pelican, will be evaluated using a similar approach to that described for sediment-probing birds. Specifically, the data on the concentrations of contaminants measured in small fish (i.e., <15 cm in length) and medium-sized fish (i.e., 15 to 30 cm) will be used in conjunction with ingestion rate information to estimate dose received. These data will be compiled by geographic area within the estuary (based on the diet and foraging range of each bird species) and compared to appropriate toxicity reference values for survival and reproduction of birds (i.e., NOAELS and LOAELs; *Table 9.6*; Appendices 2 to 17). In this evaluation, the tissue residue data for fish species collected in the estuary will be extrapolated to other fish species that are consumed by piscivorus birds, but for which data are unavailable. To the extent possible, the extrapolation will involve selecting data from measured prey species that have similar trophic levels and exposure routes as those prey species for which data are unavailable. Where appropriate, the estimated doses will also incorporate intake from other media (e.g., sediment). At this stage of the analysis, doses will be estimated using conservative inputs (e.g., upper percentiles for concentrations in prey tissues) and assumptions (e.g., assume 100% of diet is from the Calcasieu estuary). Piscivorus birds receiving doses of one or more COPCs in excess of one or more TRVs will be considered to be potentially at risk. This comparison will be done at a number of locations within the Calcasieu estuary and at several reference locations.

For those locations and COPCs for which doses exceed TRVs for piscivorus birds, additional exposure, effects and risk analyses will be undertaken to better understand the nature and severity of the risks posed. In these analyses, the conservative inputs in the exposure models will be replaced by distributions of the available data. The distributions will represent our state of knowledge regarding variability of each input parameter (e.g., spatial variability of prey tissue concentrations over the foraging range of piscivorus bird species of interest). For the effects analyses, dose-response relationships will be used rather than TRVs where possible. The resulting exposure and effects distributions can be integrated to produce risk curves that show the relationship between probability and magnitude of effect (see Section 9.2 for an overview of the planned analyses).

9.1.6 Mammalian Communities

Mammals occur in much lower numbers in the Calcasieu Estuary than birds. However, there are several aquatic-dependent mammals that occur or could occur in the estuary including river otter, mink, raccoons, and dolphins. These species play important roles in the aquatic food web by processing energy from benthic invertebrates (e.g., bivalves and crabs), fish, and, to a lesser extent, birds.

Assessment Endpoint - Survival, Growth, and Reproduction of Aquatic-Dependent Mammal Species. Aquatic-dependent mammals can be classified based on their feeding habits into two main groups: omnivorous mammals (i.e., species that eat a wide variety of plants and animals, including aquatic organisms) and piscivorus mammals (i.e., species that eat fish).

Although mammals can be exposed to environmental contaminants through dermal contact with contaminated surface water or sediments (i.e., dermal exposure) or consumption of contaminated surface water, the bulk of their exposure is associated with the consumption of contaminated prey items. This is especially true for persistent and bioaccumulative COPCs. Therefore, it is important to evaluate the effects of contaminated prey items on the survival and reproduction of mammals (*Table 9.5*).

Risk Questions/Testable Hypotheses. To support the BERA, the assessment of the risks of environmental contaminants on mammals should be designed to answer several key risk questions, including:

- Does the dose of contaminants received by omnivorous mammals from consumption of the tissues of prey species and from other media in the Calcasieu Estuary (e.g., sediment) exceed the toxicity reference values (TRVs) for survival or reproduction of mammals? If yes, what are the probabilities of effects of differing magnitude for survival and/or reproduction of omnivorous mammals?
- Does the dose of contaminants received by piscivorus mammals from consumption of the tissues of prey species and from other media in the Calcasieu Estuary (e.g., sediment) exceed the toxicity reference values (TRVs) for survival or reproduction of mammals? If yes, what are the probabilities of effects of differing magnitude for survival and/or reproduction of piscivorus mammals?

Measurement Endpoints. A number of measurement endpoints will be used to evaluate risks to aquatic dependent mammals associated with the consumption of contaminated prey items and other contaminated media. First, the potential for adverse effects on omnivorous mammals (e.g., raccoon) will be evaluated using tissue chemistry data from prey species and foraging information for the omnivorous mammal species of interest. Specifically, the dose received by raccoons will be estimated by multiplying food ingestion rates (normalized to body weight) by the concentrations of contaminants in invertebrates and small fish (i.e., <15 cm in length). In this evaluation, the tissue residue data for invertebrates (e.g., shrimp and polychaetes) and fish that are collected in the estuary will be assumed to be similar to that for the other aquatic organisms that are consumed by omnivorous mammals (e.g., fidler crabs, juvenile blue crabs), but not targeted in the sampling program. Where appropriate, the estimated doses will also incorporate intake from other media (e.g., sediment). At this stage of the analysis, doses will be estimated using conservative inputs (e.g., upper percentiles for concentrations in prey tissues) and assumptions (e.g., assume 100% of diet is from the Calcasieu estuary). The estimated doses will then be compared to appropriate toxicity reference values for the survival and reproduction of mammals (i.e., NOAELS and LOAELs; *Table 9.6*; Appendices 2 to 17). Omnivorous mammals receiving doses of one or more COPCs in excess of one or more TRVs will be considered to be potentially at risk. This comparison will be done at a number of locations within the Calcasieu estuary and at several reference locations.

For those locations and COPCs for which doses exceed TRVs for omnivorous mammals, additional exposure, effects and risk analyses will be undertaken to better understand the nature and severity of the risks posed. In these analyses, the conservative inputs in the exposure models will be replaced by distributions of the available data. The distributions will represent our state of knowledge regarding variability of each input parameter (e.g., spatial variability of prey tissue concentrations over the foraging range of raccoons). For the effects analyses, dose-response relationships will be used rather than TRVs, where possible. The resulting exposure and effects distributions can be integrated to produce risk curves that show the relationship between probability and magnitude of effect (see Section 9.2 for an overview of the planned analyses).

The potential for adverse effects on piscivorus mammals, such as otters and mink, will be evaluated using tissue chemistry data from prey species and foraging information for the piscivorus mammal species of interest. Specifically, the dose received by otters and mink will be estimated by multiplying food ingestion rates (normalized to body weight) by the concentrations of contaminants measured in medium-sized fish (i.e., 15 to 30 cm) and large fish (i.e., 30 to 90 cm). In this evaluation, the tissue residue data for fish collected in the estuary will be assumed to be similar to that for the other fish species consumed by piscivorus mammals, but will not be targeted in the sampling program. Where appropriate, the estimated doses will also incorporate intake from other media (e.g., sediment). At this stage of the analysis, doses will be estimated using conservative inputs (e.g., upper percentiles for concentrations in prey tissues) and assumptions (e.g., assume 100% of diet is from the Calcasieu estuary). The estimated doses will then be compared to appropriate toxicity reference values for the survival and reproduction of mammals (i.e., NOAELS and LOAELs; *Table 9.6*; Appendices 2 to 17). Piscivorus mammals receiving doses of one or more COPCs in excess of one or more TRVs will be considered to be potentially at risk. This comparison will be done at a number of locations within the Calcasieu estuary and at several reference locations.

For those locations and COPCs for which doses exceed TRVs for piscivorus mammals, additional exposure, effects and risk analyses will be undertaken to better understand the nature and severity of the risks posed. In these analyses, the conservative inputs in the exposure models will be replaced by distributions of the available data. The distributions will represent our state of knowledge regarding variability of each input parameter (e.g., spatial variability of prey tissue concentrations over the foraging range of mink or otters). For the effects analyses, dose-response relationships will be used rather than TRVs where possible. The resulting exposure and effects distributions can be integrated to produce risk curves that show the relationship between probability and magnitude of effect (see Section 9.2 for an overview of the planned analyses).

9.2 Analysis Plan for the Calcasieu Estuary BERA

Inferences in ERAs are made by weight of evidence rather than traditional scientific standards of proof (USEPA 1992). The weight of evidence approach is a process by which the results of biological surveys, monitoring studies and field and laboratory toxicity tests are related to an assessment endpoint to evaluate risks to the environment (USEPA 1997a). A formal weight of evidence can range from a simple qualitative assessment to a highly quantitative evaluation. In either case, however, the weight of evidence should provide documentation that elucidates the risk assessors thought process when assessing risk. The term "line of evidence" as used in this discussion follows the definition provided in *Guidelines for Ecological Risk Assessment* (USEPA 1998a), "Information derived from different sources or by different techniques that can be used to describe and interpret risk estimates." Unlike the term "weight of evidence" it does not imply assignment of qualitative or quantitative weightings to information. There are three general lines of evidence under which most measurement endpoints fall (Suter *et al.* 1995; USEPA 1997a):

- Survey data (i.e., physical, chemical, and/or biological data) that indicate the state of the receiving environment;
- Media specific or *in situ* toxicity data that indicate whether the contaminated media at the site are toxic (i.e., laboratory or *in situ* toxicity testing); and,
- Single chemical toxicity data that indicate the expected toxic effects of the chemical at concentrations occurring at the site.

Ideally, each weight of evidence assessment would include all three of the general lines of evidence. To the extent possible, the Calcasieu BERA will include information from the three general lines of evidence in reaching conclusions about risks to each of the assessment endpoints. In some cases, however, it is technically difficult, too expensive, or inappropriate to gather certain lines of evidence (e.g., *in situ* toxicity tests on threatened and endangered species, such as the brown pelican). The following outlines the general weight of evidence approach that will be used in the Calcasieu BERA. Subsequent sections then describe the approaches and methods that will be used to characterize risks for the aquatic and wildlife assessment endpoints.

The Calcasieu BERA will use the weight of evidence approach developed by Glenn Suter and colleagues at Oak Ridge National Laboratory (ORNL), Oak Ridge, Tennessee (Suter *et al.* 1995; Suter 1996; 1997). The ORNL approach begins by summarizing the available lines of evidence for each assessment endpoint. The process of weighing the evidence amounts to determining what estimate of risk is most likely given those results. If all of the lines of evidence are consistent, the result of the weighing of evidence is clear. If there are inconsistencies, however, a weighting of evidence must occur. If required, weights are assigned to each line of evidence or study based on six attributes:

- Relevance of the study to the assessment endpoint;
- Strength of the exposure-response relationship;
- Appropriateness of the study temporal scope;
- Appropriateness of the study spatial scope;
- Quantity of data; and,
- Quality of data.

The weights that are assigned to the various lines of evidence may be qualitative or quantitative. In this assessment, we will assign high, medium or low weights to each line of evidence. *Table 9.7* presents an example of a simple summary of the results of the ORNL weight of evidence process. The "evidence" column provides a brief description of the line of evidence being evaluated; the "results" column uses a + symbol if the evidence is consistent with significant effects to the assessment endpoint, a – symbol if it is inconsistent with significant effects, and ± symbol if it is too ambiguous to assign to either category; the "weight" column indicates the relative reliability and credibility of the conclusions for that line of evidence; and the "explanation" column presents a short summary of the results of the risk characterization for that line of evidence. The last line of the table presents the weight of evidence based conclusion concerning the significance of the risk and a brief statement describing the basis for this conclusion.

The final step of the risk analysis is to develop a description of risk (USEPA 1997a). The risk description is done separately for each assessment endpoint and generally has two components: (1) provision of information that can be used to judge the seriousness of the risks, and (2) an indication of the contaminant concentrations in each environmental medium that represent the threshold concentration or range of concentrations, below which risks are expected to be negligible (USEPA 1997a). To provide an indication of the seriousness of the risks, information will be provided on the likelihoods of observing effects of differing magnitude, the location and areal extent of existing contamination above thresholds for different levels risk, potential consequences of adverse effects on the ecosystem, the expected amount of time for which the contaminants will remain at elevated levels in the environment, and potential for natural recovery. The assessments of risks to aquatic life and wildlife are designed to determine how risk changes along gradients of chemical contamination (e.g., by selecting multiple locations with varying levels of contamination). This design facilitates the identification of thresholds below which risks become negligible for different contaminants and aquatic and wildlife receptors. Such information is one of the required inputs to the risk management process (USEPA 1997a).

9.2.1 Aquatic Assessment Endpoints

The ecological risks associated with exposure to contaminated environmental media will be evaluated for four groups of aquatic receptors, including the microbial community, aquatic plant community, benthic invertebrate community, and fish community. These assessments will be conducted to answer four main questions, including:

- Does the presence of COPCs in overlying water, porewater, sediments, or biological tissues pose significant risk to the aquatic receptor group under consideration?
- What is the nature, severity, and areal extent of the risk to the aquatic receptor group under consideration?
- Which COPCs, by media type, are causing or substantially contributing to the risk to the aquatic receptor group under consideration?
- What are the concentrations of COPCs, by media type, that are associated with negligible risk to the aquatic receptor group under consideration?

Each of the assessments of risk to the selected receptor groups will consist of three main components, including exposure assessment, effects assessment, and risk estimation. The objectives of the exposure characterization are to identify the receptor, describe the pathway of the stressor from the source to each aquatic receptor, and describe the intensity and areal extent of contact with the stressor (USEPA 1998a). The objectives of the effects characterization are to describe the effects elicited by the stressor, to link those effects to the aquatic assessment endpoints, and to evaluate how the effects change at various levels (i.e., concentrations) of the stressor (USEPA 1998a). Integration of the exposure and effects characterizations provides a basis for estimating risks to ecological receptors and identifying contaminant concentrations below which risks are considered to be negligible. The procedures that will be used to conduct these assessments for each receptor group are described below.

9.2.1.1 Microbial Communities

Evaluations of the risks to microbial communities will be conducted in three steps, including exposure assessment, effects assessment, and risk estimation. The first step in this process will involve exposure characterization. While microorganisms can be exposed to environmental contaminants via several exposure routes (e.g., direct contact with contaminated water, processing of contaminated plant or animal tissues), direct contact with contaminated sediments represents the primary route of exposure in the Calcasieu Estuary. Therefore, the toxic substances that partition into sediments are likely to have the highest potential for adversely affecting the activity of microbiota. The intensity and areal extent of exposure to chemical stressors will be evaluated using the results of solid phase toxicity tests with the bacterium, *Vibrio fisheri*. In this analysis, exposure intensity will be evaluated based on the incremental response (i.e., EC_{50} bioluminescence; as a surrogate for microbial activity) that is observed in bacteria exposed to Calcasieu Estuary sediments compared to the lower 95% confidence limit (LCL) response that is observed in bacteria exposed to reference sediments. The magnitude of the incremental response (i.e., relative to the LCL) will be used to delineate the intensity of exposure of microbiota to COPCs in the estuary. The areal extent of exposure will be evaluated by mapping the results of toxicity tests, for each sampling station and identifying the samples in which the exposure intensity is higher than that for reference sites.

In the second step of the risk analysis, the effects on the microbial community that are associated with exposure to contaminated sediments will be assessed. The bioluminescence of the bacterium, *Vibrio fisheri*, has been selected as the measurement endpoint for assessing effects on the microbial community. More specifically, this measurement endpoint was selected as a surrogate for microbial metabolic rate, which is considered to provide an indicator of microbial activity (i.e., the rate at which microbiota perform essential ecological processes, such as processing organic carbon). By establishing this linkage with the assessment endpoint (i.e., activity of the microbial community), it is possible to identify the sediment samples in which adverse effects on the activity of the microbial community are likely to occur. In the final step of the effects assessment, multivariate regressions will be conducted (i.e., using the COPC concentrations as the independent variables and response in the toxicity tests as the dependent variable) to identify the substances that are causing or substantially contributing to toxicity to microbiota (i.e., the substances for which significant regressions are obtained; $r^2 > 0.5$; $P<0.1$).

The final step in the analysis will involve risk estimation. In this analysis, the concentration-response data for each putative causal agent will be modeled (i.e., using logistic regressions) to determine dose-response relationships that can be used to estimate the probability of observing toxicity at various contaminant concentrations. In turn, these relationships will be used to estimate risks to the microbial community throughout the estuary using sediment chemistry data collected in the Phase I and Phase II sampling programs. These dose-response relationships will also provide a basis for identifying the concentrations of individual COPCs and groups of COPCs (e.g., total PAHs, total PCBs) that are associated with negligible risks to the microbial community.

9.2.1.2 Aquatic Plant Communities

The risks to aquatic plant communities in the Calcasieu Estuary will be evaluated by conducting an exposure assessment, an effects assessment, and risk estimation. The first step in this process will involve exposure characterization. Aquatic plants can be exposed to environmental contaminants via several exposure routes, including direct contact with contaminated water, contaminated sediments, and contaminated porewater. Of these, direct contact with contaminated porewater is considered to represent the exposure scenario that is most likely to result in adverse effects on aquatic plants (i.e., contaminants are likely to be present at higher concentrations in porewater than in surface waters and contaminants are likely to be more bioavailable to plants in porewater than in sediments). For this reason, the intensity and areal extent of exposure to chemical stressors will be evaluated using the results of porewater toxicity tests with the alga, *Ulva lactuca*. In this analysis, exposure intensity will be evaluated based on the incremental response that is observed in algae (i.e., germination rate, germling length, and cell number) exposed to porewater from Calcasieu Estuary sediments compared to the LCL response that is observed in algae exposed to porewater from reference sediments. The areal extent of exposure will be evaluated by mapping the results of toxicity tests, for each sampling site and identifying the samples in which growth rates were lower than LCL for reference sites.

The effects on the aquatic plant community that are associated with exposure to porewater from contaminated sediments will be assessed. In this analysis, the germination success, germling length and cell number in the alga, *Ulva lactuca*, (i.e., surrogates for the growth and survival of aquatic plants) were selected as the measurement endpoints for assessing the survival and growth of aquatic plants (i.e., the assessment endpoint). By establishing this linkage with the assessment endpoint, it is possible to identify the porewater samples in which adverse effects on the survival or growth of aquatic plants are likely to occur. Mapping of these data provides a basis for assessing the areal extent of potential effects on aquatic plants. In the final step of the effects assessment, multivariate regressions will be conducted (i.e., using the COPCs as the independent variables and response as the dependent variable). The results of these analyses will be used to identify the substances that are causing or substantially contributing to toxicity to aquatic plants (i.e., the substances for which significant regressions are obtained; $r^2 > 0.5$; $P<0.1$).

The final step in the analysis will involve risk estimation. In this analysis, the concentration-response data for each putative causal agent will be modeled (i.e., using logistic regressions) to determine dose-response relationships that can be used to estimate the probability of observing toxicity at various contaminant concentrations. In turn, these relationships will be used to estimate risks to the aquatic plant community throughout the estuary using sediment chemistry data collected in the Phase I and Phase II sampling programs. These dose-response relationships will also provide a basis for identifying the concentrations of individual COPCs and groups of COPCs (e.g., total PAHs, total PCBs) that are associated with negligible risks to the aquatic plant community.

9.2.1.3 Benthic Invertebrate Communities

The risks to benthic invertebrate communities will be evaluated by conducting an exposure assessment, an effects assessment, and risk estimation. The first step in this process will involve exposure characterization. Benthic invertebrates can be exposed to environmental contaminants via several exposure routes, including direct contact with contaminated water, sediments, and porewater. Ingestion of contaminated sediments and food also represent potential routes of exposure for benthic invertebrates. Of these, direct contact with contaminated sediments and porewater have the highest potential for adversely affecting benthic invertebrates.

For benthic invertebrates, the intensity and areal extent of exposure to chemical stressors will be evaluated using three measures of exposure, including sediment chemistry data, porewater chemistry data, and tissue chemistry data (i.e., from field-collected samples of invertebrate tissues and laboratory bioaccumulation tests). In this analysis, exposure intensity will be evaluated in several ways. First, the upper 95% confidence level (UCL) of background concentrations of COPCs will be determined using the sediment, porewater, and tissue chemistry data for reference areas; samples from the Calcasieu Estuary with contaminant concentrations in excess of the UCL will be considered to have incremental exposure to one or more COPCs. Next, the measured concentrations of individual COPCs and groups of COPCs will be compared to the corresponding SQGs; samples from the Calcasieu Estuary with concentrations of one or more COPCs in excess of the SQGs will be considered to be sufficiently contaminated to adversely affect sediment-dwelling organisms. Numerical SQG-quotients (i.e., calculated as the measured COPC concentration divided by the corresponding SQG) will be calculated for each COPC for which numerical sediment quality guidelines are available (*Table 9.2*). The SQG-quotient calculated for each substance provides a basis for evaluating the relative intensity of exposure to individual COPCs, as SQG-quotients of greater than one are predicted to adversely affect benthic invertebrates (Long and MacDonald 1998; USEPA 2000c). Finally, mean SQG-quotients will be calculated for each sediment sample and used to evaluate the relative intensity of exposure to mixtures of contaminants (USEPA 2000c). The areal extent of exposure will be evaluated by mapping the sediment chemistry data.

Effects on the benthic invertebrate community that are associated with exposure to contaminated sediments or porewater from contaminated sediments will be assessed in the second step of the risk analysis. Five lines of evidence (including eleven measurement endpoints) were selected to evaluate the survival, growth, and reproduction of benthic invertebrates:

- Whole sediment chemistry;
- Porewater chemistry;
- Whole sediment toxicity;
- Porewater toxicity; and,
- Benthic invertebrate community structure (*Table 9.1*).

Importantly, nine of the 11 measurement endpoints provide direct measures of effects on benthic invertebrates. For the two other measurement endpoints, dose-response models from laboratory toxicity tests (i.e., for porewater chemistry) and analyses of field-collected sediment samples (i.e., for sediment chemistry) provide a basis for predicting whether samples are likely to be toxic, using the chemistry data alone. By establishing these linkages with the assessment endpoint, it is possible to identify the sediment and porewater samples in which adverse effects on the survival, growth, or reproduction of benthic invertebrates have occurred. The relative intensity of effects will be evaluated by determining the proportion of measurement endpoints which demonstrate effects in each sample (i.e., based on the number of lines of evidence that indicate effects have occurred). Sediment quality triad contingency tables will be used to assist in the interpretation of these multiple lines of evidence relative to effects on benthic invertebrates (MacDonald and Ingersoll 2001).

In the final step of the analysis, risks to the benthic invertebrate community associated with exposure to contaminated sediments will be estimated on an estuary wide basis. In this evaluation, the logistic models that have been developed to describe the relationships between sediment chemistry (i.e., as indicated by mean SQG-quotients) and sediment toxicity (Long and MacDonald 1998; USEPA 2000c; Field *et al.* In review) will be used to estimate the probability of observing sediment toxicity in sediment samples that have been collected from the Calcasieu Estuary using sediment chemistry data. This information can then be used directly to estimate risks to the benthic invertebrate community throughout the estuary. These dose-response relationships will also be validated using matching sediment chemistry and toxicity data from the Calcasieu Estuary and used to identify the concentrations of contaminants in whole sediments that pose negligible risks to benthic invertebrates.

9.2.1.4 Benthic Fish Communities

The risks to benthic fish communities will be evaluated by conducting an exposure assessment, an effects assessment, and subsequent risk estimation. The first step in this process will involve exposure characterization. Benthic fish, which typically include omnivorous and carnivorous species, can be exposed to environmental contaminants via several exposure routes, including direct contact with contaminated surface water, contaminated sediments, and contaminated porewater. In addition, consumption of contaminated prey species represents another potential exposure pathway for benthic fish. For pelagic fish, direct contact with contaminated surface water and consumption of contaminated prey species represent the most important exposure pathways. Four measurement endpoints were selected to evaluate the intensity and areal extent of exposure of benthic and pelagic fish to chemical stressors, including:

- Surface water chemistry;
- Porewater chemistry;
- Porewater toxicity tests with the red drum, *Sciaenops ocellatus*; and,
- Tissue chemistry for species with relatively small home ranges (e.g., polychaetes; juvenile crabs, gulf killifish).

In this analysis, exposure intensity will be evaluated primarily using the surface water and porewater chemistry data. First, the 95% UCL of background concentrations of COPCs in surface water, porewater, and fish tissues will be determined using the water chemistry data for reference sites; benthic and/or pelagic fish within the Calcasieu Estuary will be considered to have incremental exposure to COPCs when the concentrations of one or more contaminants exceed the 95% UCL. The measured concentrations of COPCs in surface water and porewater will then be divided by the corresponding water quality criteria (WQC; *Table 9.3*; USEPA 1999) to calculate WQC-quotients. Adverse effects on fish are predicted when WQC-quotients exceed one, with the magnitude of the effects increasing with increasing quotients. In addition, exposure intensity will be evaluated based on the incremental response (i.e., larvae survival) that is observed in red drum exposed to porewater from Calcasieu Estuary sediments compared to the 95% LCL response (larvae survival) that is observed in red drum exposed to porewater from reference sediments. The areal extent of exposure will be evaluated by mapping the results of chemical evaluations and toxicity tests for each sampling location and identifying the samples in which chemical concentrations exceed the 95% UCL and larvae survival rates were significantly lower than that for reference sites.

Effects on the benthic and pelagic fish community that are associated with exposure to porewater from contaminated sediments will be assessed in the second step of the risk analysis. Three measurement endpoints will be used to assess the survival, growth, and reproduction of benthic and pelagic fish species. Surface water or porewater samples with one or more COPCs at concentrations in excess of the WQC will be considered to be sufficiently contaminated to adversely affect the survival, growth, or reproduction of benthic and/or pelagic fish. Additionally, the results of red drum toxicity tests will be used to identify sediment samples in which the concentrations of COPCs in porewater are sufficient to adversely affect the survival or reproduction of benthic and/or pelagic fish.

In the final step of the analysis, risks to the benthic and pelagic fish communities associated with exposure to contaminated environmental media will be estimated on an estuary-wide basis. In this evaluation, surface water and porewater chemistry data will be used in conjunction with dose-response relationships from laboratory toxicity tests (i.e., obtained from the USEPA AQUIRE database) to estimate the probability of observing toxicity in the Calcasieu Estuary. In addition, the concentration-response data from the red drum toxicity tests conducted on field-collected samples will be modeled for individual substances and/or groups of substances (i.e., using logistic regressions) to determine dose-response relationships that can be used to estimate the probability of observing toxicity at various contaminant concentrations. This information can then be used, in conjunction with ambient water chemistry data, to estimate risks to the benthic fish throughout the estuary. In addition, these data will be used to identify the concentrations of COPCs that pose negligible risks to benthic and pelagic fish species.

9.2.2 Wildlife Assessment Endpoints

The primary line of evidence to be used for estimating risk to wildlife receptors will be to compare estimated exposure for a single (e.g., HCB) or group (e.g., PCBs) of COPCs to appropriate effects endpoints derived from laboratory bioassays.

Overview

For each COPC and wildlife receptor scenario, an initial assessment will be carried out to determine which substances can be dropped from further consideration (i.e., risk is considered negligible) and which ones require more detailed analyses. For these initial analyses, conservative estimates of exposure will be developed (i.e., focus on the most contaminated areas and use upper 95% confidence limits for exposure model inputs) and compared to conservative wildlife benchmarks (see *Table 9.6*). When the resulting quotient (quotient = exposure ÷ effects) exceeds one, a more refined assessment will be conducted. In this phase of the assessment, a probabilistic approach will be used to estimate exposure. This essentially involves replacing the point estimates used as inputs to the exposure model with distributions that incorporate uncertainty about the values of the input parameters. Each resulting exposure distribution will be combined with the corresponding dose-response curve (where available) to generate a risk curve that shows the relationship between probability and magnitude of effect. Risk curves provide a great deal more information to risk managers and stakeholders and can be used to derive cleanup levels (Moore *et al.* 1999a). The remainder of this section provides a description of how the probabilistic risk assessment will be conducted as well as descriptions of how exposure assessment, effects assessment, and risk estimation will proceed for wildlife receptors.

General Mechanics of a Probabilistic Risk Assessment

Finkel (1990) developed a set of guidelines for conducting a probabilistic risk assessment that includes the following six sequential steps:

1. Identify the desired risk metric for each assessment endpoint in the analysis (e.g., growth rate impairment of mink kits). Also critical at this stage is to precisely define the spatial and temporal scales of the assessment. The remaining five steps need to be followed separately for each measurement and/or assessment endpoint.

2. Specify the model equation that will estimate risk (*Figure 9.1*).

3. Generate a distribution for each input variable [also referred to as probability density functions (PDFs)] in the risk equation (*Figure 9.1*). The choice of distribution generally depends on: (i) the form of the observed data, which may be determined by graphical or statistical curve-fitting techniques; and, (ii) our basic understanding of the system so that we may theorize about the distributions that best describe the underlying reality (Hattis and Burmaster 1994). Some of the difficulties of selecting appropriate distributions, particularly when data are lacking, are discussed by Haimes *et al.* (1994). In uncertainty analyses of any type, the rationale for each input PDF selected must be provided (Burmaster and Anderson 1994).

4. Generate the output distribution by combining the input PDFs as specified in the risk equation (*Figure 9.1*). This step typically involves Monte Carlo simulation, but there are a variety of other possible QUA methods (e.g., 2nd order Monte Carlo, probability bounds analysis, Bayes' theorum).

5. Fine tune the analysis (*Figure 9.1*). One may use the results of a sensitivity analysis to determine those input PDFs that had an important influence on the estimate of risk. Such input PDFs should be re-examined to ensure that the data used and the distributions selected are scientifically acceptable. Input

PDFs may also have to be adjusted to account for dependencies between important variables (Ferson and Burgman 1995). Once the input PDFs (and, if necessary, the risk equation) have been fine tuned, the analysis is repeated and a refined risk estimate generated. Fine tuning of the risk analysis often involves numerous iterations.

6. Summarize the results, highlighting important implications for risk managers and stakeholders. The major output of the analysis is a quantitative or graphical description of uncertainty or probability of an effect. Such outputs are usually summarized as probability density functions or cumulative probability distributions. The objective is to ensure that risk managers and stakeholders understand the results of the uncertainty analysis, and the impact of the uncertainties on the conclusions of the risk assessment and potential risk management decisions. Managers and stakeholders should also be briefed on any unresolved scientific controversies and provided with information on the magnitude and relative importance of uncertainties not captured in the analysis (Finkel 1990; Covello and Merkhofer 1993).

Finkel (1990) and Morgan and Henrion (1990) provide excellent overviews of probabilistic risk assessment and the available methods. Burmaster and Anderson (1994), USEPA (1997b), and Warren-Hicks and Moore (1998) list and describe principles of good practice in performing or reviewing probabilistic risk assessments.

Routes of Exposure and Spatial and Temporal Scales

The exposure analyses will be for those time periods when birds and mammals are in the primary areas of concern of the Calcasieu Estuary (see Chapter 2). Thus, no attempt will be made to estimate exposure of wildlife receptors to COPCs during the times they are elsewhere.

The spatial scale for most wildlife exposure assessments will correspond to the foraging range of the receptor of interest. When foraging ranges are small (e.g., kingfishers), multiple exposure assessments will be carried out for the areas in the Calcasieu Estuary where they could occur (e.g., shorelines with overhanging perches). The intention is not to focus solely on worst-case exposures, but instead to estimate how exposure varies spatially across the Calcasieu Estuary. Each of these areas would be approximately equal to the foraging range of the receptor of interest. When foraging ranges are large (e.g., raptors), the receptors effectively "average" their exposures over space and thus exposure assessments may need to be combined across different portions of the Calcasieu Estuary (e.g., combining contaminated areas of concern with less contaminated areas).

For the persistent and bioaccumulative COPCs of most concern for wildlife receptors, temporal "averaging" of exposures is expected. In these cases, the objective will be to estimate average daily exposures over long durations. These exposure estimates would then be compared to chronic effects benchmarks or dose-response curves. In cases where releases are not continuous (e.g., spills, pesticide applications), the general exposure model described below could be altered to have a time step that accounts for chemical degradation or losses over time.

For COPCs and receptors where spatial and temporal averaging are expected, we will use 95% upper confidence limits for the chemical concentration variables in the initial conservative analyses aimed at determining which COPC-receptor combinations require further probabilistic analyses. In the probabilistic risk analyses, distributions will be used for the chemical concentration variables. These distributions will account for the existing uncertainty (e.g., because of small sample sizes) about the exact values of the spatial-temporal "average" concentrations of the COPC in the media of interest.

The potential intake routes for wildlife receptors include:

- Oral ingestion of contaminants associated with diet,
- Oral ingestion of contaminants in drinking water,
- Incidental oral ingestion of contaminants in sediment or soil,
- Transdermal exposure of contaminants from direct contact with ambient water,
- Incidental oral ingestion of contaminants residues on the body surface (e.g., during preening); and,
- Inhalation of vapor phase and particulate-associated contaminants of concern.

For contaminants that are persistent and bioaccumulative, the major routes of exposure are through oral ingestion of contaminant residues associated with diet and drinking water. Of these two routes, diet is expected to be the more important route of exposure (see Moore *et al.* 1997; 1999b).

Inhalation of vapor phase is unlikely to be a dominant exposure route due to the low vapor pressure of bioaccumulative substances. There is a potential for significant exposure via oral ingestion during preening. No established and accepted model exists, however, to estimate exposure via this route. Similarly, dermal exposure as a result of contact with water, soil, sediment or other media (e.g., vegetation) cannot be estimated because established and accepted exposure models are lacking. For the most part, the preening and dermal exposure routes are unlikely to be important for wildlife receptors exposed to persistent and bioaccumulative COPCs, although they may be important for other chemicals such as pesticides immediately following application. Ingestion of soil- or sediment-associated residues may be important for species such as willet or roseate spoonbill because they consume sediments incidentally in the course of foraging for prey. In these cases, such exposure routes would be added to the general exposure model described below, using methods described in USEPA (1993) and elsewhere.

General Exposure Model

The general exposure model has the following form:

$$TDI = \left(\frac{C_w \cdot IR_w + C_{om} \cdot IR_{om} + IR_d \cdot \sum_{i=1}^{n} C_i \cdot P_i}{BW} \right) \cdot P_{sa}$$

where:

TDI	=	total daily intake of the COPC normalized to the body weight of the wildlife receptor of interest (e.g., mg/kg body weight; BW/day);
C_w	=	ambient water concentration;
IR_w	=	water intake rate;
C_i	=	concentration in the ith prey species;
P_i	=	proportion of the ith prey species in the diet;
IR_d	=	food intake rate;
C_{om}	=	concentration of contaminants in other media (e.g., sediments for sediment-probing birds);
IR_{om}	=	intake rate of other media;
BW	=	average body weight of the wildlife receptor of interest; and,
P_{sa}	=	proportion of time the receptor spends in the contaminated portion of the Calcasieu Estuary.

The general format of the intake model will be altered as needed to reflect the foraging habits of the wildlife receptor, to incorporate other major routes of exposure, or to eliminate trivial routes of exposure. For example, while an incidental sediment intake component of the model is appropriate for sediment-probing birds, it is unlikely to be necessary for raptors. Also, in some species (e.g., osprey) only a certain proportion of their time is spent foraging in the Calcasieu Estuary area. In this case, an apportioning factor (P_{sa}) is included to account for the portion of the exposure that occurs outside the contaminated estuary (and is assumed to be negligible).

In some cases, it may be advantageous to use an energetics-based model (e.g., when prey species differ considerably in gross energies or the efficiencies with which they are assimilated by the predator). In an energetics-based model, the dietary component of the above general exposure model is replaced by:

$$TDI_{diet} = MR \cdot \sum_{i=1}^{n} \frac{C_i \cdot P_i}{GE_i \cdot AE_i}$$

where:

TDI_{diet}	=	total daily intake from diet;
MR	=	average metabolic rate of the wildlife receptor;
C_i	=	concentration in the ith prey species;
P_i	=	proportion of the ith prey species in the diet;
GE_i	=	gross energy of the ith prey species; and,
AE_i	=	assimilation efficiency of the ith prey species by the wildlife receptor.

Each of the inputs to the general exposure model are described in more detail below. For the initial, conservative analyses, 95% upper confidence limits will be used for each input variable. For the probabilistic analyses, distributions will be used for each input variable. The methods for selecting and parameterizing the distributions for the input variables and the methods for propagating input variable uncertainties to the estimate of total daily intake are described in the risk characterization section below.

Concentration in Water (C_w), Diet (C_i) and Other Media (C_{om})

The levels of COPCs in fish, invertebrates and sediments at areas of concern in the Calcasieu Estuary will be obtained from the Phase II sampling program and other monitoring studies. Water samples collected during the Phase I sampling program and in other monitoring studies will be used for levels of COPCs in water. Except for periods when portions of the Calcasieu Estuary are freshwater or nearly freshwater (e.g., Lake Charles following a rain event), wildlife receptors are likely to obtain their drinking water from freshwater sources outside the Estuary. Thus, it may be necessary to use an apportionment factor to account for the portion of drinking water obtained outside the Estuary. In the case of dietary concentrations, only prey items (or reasonable surrogates) that could be consumed by the wildlife receptor of interest will be included in the exposure calculations. Concentration estimates will account for foraging patterns of wildlife receptors.

Water Intake Rate (IR_w)

Water intake rates will be estimated using allometric relationships published by Calder and Braun (1983) and elsewhere, unless measured rates are available for the wildlife receptors of interest (ROI). The general form of the allometric model is:

$$IR_w^* = a \cdot BW^b$$

where:

IR^*_w = drinking rate without considering water intake from other sources;

BW = average body weight of the wildlife receptor; and,

a and b = species-specific constants

The daily water flux rate is assumed to be for a wildlife receptor in water equilibrium, such that water balance is maintained each day. Additional sources of water are not considered by this equation, so the calculated estimate may be higher than actual. For example, water contained in food as well as water produced metabolically will decrease drinking water requirements. The calculation of water intake from food is made by multiplying the daily fresh mass of each food item consumed by the wildlife receptors by the corresponding fractional water content of that food item. The fractional water content of various food items is listed by USEPA (1993). The actual daily drinking water intake rate (IR_w) will be calculated by subtracting food water from daily drinking rates estimated using the allometric relationship. The proportion of daily water flux attributable to metabolic by-product water is assumed to be zero. This will result in a slight overestimation of the daily drinking water requirement. In some cases, water contained in diet may exceed the daily needs of animals. In effect, the above equation may produce negative IR_w values. To eliminate negative values, a logical statement will be used to equate IR_w to zero whenever diet water contributions exceed daily drinking water needs.

Metabolic Rate (MR), Dietary Intake Rate (IR_d)

Average metabolic rates or dietary intake rates for wildlife receptors of interest will be estimated using allometric relationships published by Nagy (1987), unless measured values are available. The general form of these relationships is similar to that for water intake rate.

Gross Energy (GE_i), Assimilation Efficiency (AE_i)

Metabolizable energy of a prey item is calculated by multiplying the assimilation efficiency for a predator consuming the prey item by the gross energy of the item. The food intake rate for each prey item is then estimated by dividing the metabolic rate (*MR*) of the predator by metabolizable energy. USEPA (1993) summarizes gross energies and assimilation efficiencies of various food items.

Diet (P_i)

This is a critical variable in the exposure model, but one which is often highly uncertain with opportunistic predators. For example, mink may consume fish, crayfish, muskrats or other prey depending on what is available and accessible. The relative proportions vary considerably between sites and times of the year (see USEPA 1993). Other wildlife receptors may have more predictable diets (e.g., kingfishers are primarily piscivorus). In the wildlife exposure assessments, dietary information will be obtained from studies that have conducted stomach contents (preferably), scat or other analyses.

Body Weight (BW)

Body weight is a required parameter in allometric models for water intake rate, food intake rate, free metabolic rate, and to normalize the exposure estimate. Body weights are readily available and can be obtained from the literature (e.g., USEPA 1993). For those receptors where the focus is on early life stages, we will use early life stage body weights instead of adult body weights.

Proportion of Time in the Calcasieu Study Area (P_{sa})

Some of the wildlife focal species are not expected to forage exclusively in the Calcasieu Estuary area, even at the times of the year when they reside in the area. Many raptor species, for example, forage over broad areas even over short time frames. Exposure estimates for these species will be adjusted for the amount of time they are expected to be in the Calcasieu study area. When observational data are available, they will be used to estimate P_{sa}. More likely, other approaches will be required (e.g., dividing available foraging area in the Calcasieu by average foraging area for the species of interest).

Effects Characterization

In the initial, conservative analyses, effects characterization will rely on published wildlife benchmarks, adjusted appropriately for body weight of the receptor of interest (see *Table 9.6*). In the probabilistic assessment phase, effects characterization will preferentially rely on dose-response curves, but may default to benchmarks or other estimates of effect [e.g., no observed adverse effect level (NOAEL), lowest observed adverse effect level (LOAEL)] when insufficient data are available to derive dose-response curves. Effects associated with growth, fecundity, and/or reproduction will generally be the preferred measures of effect.

When sufficient data are available, dose-response relationships for wildlife focal species and COPCs will be used to characterize effects. Generally, five or more treatments are required to develop dose-response relationships, either from a single study or from several studies that used a similar methodology. The Generalized Linear Model (GLM) framework described by Kerr and Meador (1996) and Bailer and Oris (1997) is a useful framework for deriving dose-response relationships. The framework involves using link functions to transform effects metrics (e.g., probit or logit link functions for quantal responses, log link function for count and continuous responses) and assign appropriate error distributions (e.g., binomial distribution for quantal responses, Poisson distribution for count responses, normal distribution for continuous responses). Linear regression can then be conducted on the transformed data to derive the dose-response relationship with confidence intervals. Thus, the framework can be used for all available types of response variables (see Moore *et al.* 2000). By adding a quadratic term to the linear model, the framework can be adapted to incorporate stimulation at low dose. In some cases, it may be necessary to convert concentration-response relationships to dose-response relationships by multiplying the former by the food intake rate of the bioassay species (see Moore *et al.* 1999b for an example).

Risk Characterization

Although a simple conservative and deterministic analysis of risk is generally adequate in initial assessments, a more refined approach is required to better understand risk for those scenarios for which conservative quotients exceed one. The purpose of probabilistic risk analysis is to comprehensively characterize not just the best estimate or a conservatively-biased estimate of a quantity, but the entire statistical distribution of the values the variable might take on. This includes the "tail risks" associated with relatively rare but serious extreme events such as a large number of animals receiving very large doses of a contaminant. Such an approach is more comprehensive and informative than an analogous screening-level approach because it can make use of virtually all the relevant empirical data. There is a growing consensus that probabilistic risk analyses serve an invaluable role in ERAs. USEPA guidance on how to conduct such analyses in Superfund and other assessments is now available (USEPA 1997b; 1999b) and will be used to guide the refined assessments for wildlife in the Calcasieu BERA.

Over the past decade, most risk analysts have come to agree that it is important to distinguish between different forms of uncertainty (Hoffman and Hammonds 1994; Cullen and Frey 1999). The first kind of uncertainty is *incertitude* that arises from measurement error, missing data, non-detects, incomplete information about mechanism, and other limitations to scientific knowledge. The second kind of uncertainty is *variability*. Variability arises from heterogeneity among individuals in a population or from stochasticity through space and time. There are differences between these two kinds of uncertainty that become important for risk management. For example, incertitude, but not variability, can be reduced by further empirical effort. Most risk analysts try to avoid confounding the two kinds of uncertainty to facilitate better risk management planning. Another important advantage of handling incertitude and variability separately is that each quantitative result from an assessment can include an accounting of its own reliability in the form of interval bounds or confidence limits (*Figure 9.2*).

In the Calcasieu BERA, we will use two methods for propagating uncertainty in refined risk assessments: Monte Carlo simulation, and probability bounds analysis (USEPA 1997b). Monte Carlo simulation is a widely used approach to probabilistic risk assessment. It requires the specification of the statistical distributions for each of the input variables and their interdependencies as measured by correlations. Computer software such as Crystal Ball or @Risk is used to 'sample' from these distributions and evaluate the risk expression many times so as to build up a histogram that serves as the estimate of the full distribution of exposure or risk (*Figure 9.1*).

Probability bounds analysis is an exact numerical approach (not based on simulation) that takes as input the same probability distributions used in Monte Carlo simulation, or, when they are difficult to specify precisely, bounds on these distributions and rigorously computes bounds on the exposure or risk output. The wider the bounds on the output, the less confidence we have in the estimates of exposure derived from the Monte Carlo simulation. Probability bounds analysis is also useful when independence assumptions between input variables are untenable (such as between sediment concentration and concentration in polychaete tissues), or when sparse empirical data make it difficult to quantify the correlations among variables.

In the Calcasieu BERA, Monte Carlo simulation will be used to generate the "best" estimate for the exposure distribution. Unless theoretical or empirical knowledge dictate otherwise, input distributions will be assigned as follows: lognormal distributions for variables that are right skewed with a lower bound of zero and no upper bound (e.g., tissue concentrations), beta distributions for variables bounded by zero and one (e.g., proportion of a prey item in the diet), normal distributions for variables that are symmetric and not bounded by an upper limit (e.g., body weight), and point estimates for minor variables (e.g., concentration in water for persistent and bioaccumulative COPCs). For some input variables, however, it is likely to be difficult to precisely specify the distribution parameters because of limited data availability (e.g., diet of opportunistic predators, proportion of time spent in the Calcasieu Estuary area). In these cases, bounds can be specified that incorporate all possible values for the variable. Probability bounds analysis will then be conducted to generate bounds on the exposure distribution produced by Monte Carlo analysis (analogous to confidence intervals on a dose-response curve). The resulting exposure estimates can then be combined with dose-response relationships to derive risk curves that specify the relationship between probability and magnitude of effect (*Figure 9.3*). If dose-response relationships cannot be derived, then probabilities of exceeding benchmarks or other effects metrics (e.g., NOAEL, LOAEL) will be estimated.

9.3 Uncertainty Analysis Plan

ERAs are uncertain because of the complexity of ecological systems and the economic costs associated with collection of the data required to predict the behavior of such systems. However, the vast majority of ERAs conducted to date have been based on conservative quotients that have not been supported by a quantitative uncertainty analysis. An uncertainty analysis, if performed, has been typically restricted to a list of sources of uncertainty and perhaps qualitative statements of believability or confidence in the estimated quotients. As a result, risk managers and interested parties are not aware of the extent of uncertainty in the risk assessment and its consequences to the decision-making process.

An open and explicit process of uncertainty analysis can reduce suspicion and misunderstandings. Many jurisdictions employing ERA as part of the environmental decision-making process have recently begun to employ the use of probabilistic risk assessment in higher tier assessments (e.g., Environment Canada - Priority Substances Assessment Program, USEPA - Office of Pesticide Products). The objective of this section is to describe sources of uncertainty in the Calcasieu BERA and describe how they will be dealt with for both aquatic and wildlife endpoints.

9.3.1 Aquatic Endpoints

There are a number of sources of uncertainty in assessments of risk to aquatic receptors, including uncertainties in the conceptual model, in the exposure assessment, and in the effects assessment. As each of these sources of uncertainty can influence the estimations of risk, it is important to describe and, when possible, quantify the magnitude and direction of such uncertainties. In this way, it is possible to evaluate the level of confidence that can be placed in the assessments conducted using the various lines of evidence. The various sources of uncertainty are discussed below.

Uncertainties in the Conceptual Model - The conceptual model is intended to define the linkages between stressors, potential exposure, and predicted effects on ecological receptors. As such, the conceptual model provides the scientific basis for selecting assessment and measurement endpoints to support the risk assessment process. Potential uncertainties arise from lack of knowledge regarding ecosystem functions, failure to adequately address spatial and temporal variability in the evaluations of sources, fate, and effects, omission of stressors, and overlooking secondary effects (USEPA 1998a). In this analysis, uncertainties associated with the conceptual model will be explicitly identified and their impact on the results of the risk assessment will be discussed. The types of uncertainties that are likely to be identified in this analysis include uncertainties associated with the identification of COPCs, environmental fate and transport of COPCs, exposure pathways, receptors at risk, and ecological effects.

Uncertainties in the Exposure Assessment - The exposure assessment is intended to describe the actual or potential co-occurrence of stressors with receptors. As such, the exposure assessment identifies the exposure pathways and the intensity and extent of contact with stressors for each receptor or group of receptors at risk. There are a number of potential sources of uncertainty in the exposure assessment, including measurement errors, extrapolation errors, and data gaps.

In this assessment, two types of measurements will be used to evaluate exposure of aquatic receptors to COPCs, including chemical analyses of environmental media and toxicity tests conducted using indicator species. Relative to the water, sediment, and tissue chemistry data, analytical errors and descriptive errors represent potential sources of uncertainty. Three approaches will be used to address concerns relative to these sources of uncertainty. First, analytical errors will be evaluated using information on the accuracy, precision, and detection limits (DL) that are generated to support the Phase I and Phase II sampling programs. Second, all data entry, data translation, and data manipulations will be audited to assure their accuracy. Finally, statistical analyses of resultant data will be conducted to evaluate data distributions, identify the appropriate summary statistics to generate, and evaluate the variability in the observations. Potential measurement errors associated with toxicity tests will be evaluated using negative control results, positive control results, and the results obtained from samples collected in the reference areas.

There are several potential sources of extrapolation errors in the BERA of the Calcasieu Estuary. First, indicator species have been selected to evaluate the potential for exposure for certain groups of aquatic receptors (e.g., information on the bacterium, *Vibrio fisheri*, will be used to assess exposure of decomposers to sediment-associated contaminants). Second, in some cases, the pathways selected to evaluate exposure to certain receptors were incomplete. Third, the sediments used to support the isolation of porewater will be collected in deposition areas of watercourse channels that are dominated by soft sediments. As aquatic plants do not normally grow in these areas, the actual exposures to COPCs will not be directly evaluated. The implications of such extrapolations on the results of the BERA will be described and, to the extent possible, quantified in the uncertainty analysis.

Data gaps also represent a source of uncertainty in the assessments of exposure for aquatic receptors. For example, limitations on the available data on the chemical composition of surface waters will constrain the assessment of exposure due to direct contact with or ingestion of surface waters. Because it is difficult to fully characterize the temporal and spatial variability of surface water quality during short-duration sampling programs, collection of water quality data is not recommended for the Phase II sampling program. Rather, historical data and data from the Phase I sampling program will be used to assess exposures to COPCs that partition into surface water. Likewise, there are difficulties associated with the collection of data on the chemical composition of the surface microlayer and, therefore, collection of such data is not recommended for the Phase II sampling program. As a result, it will not be possible to estimate exposure to COPCs via this pathway. The implications of such data gaps will be described and, to the extent possible, quantified in the uncertainty analysis.

Uncertainties in the Effects Assessment - The effects assessment is intended to describe the effects that are caused by stressors, link them to the assessment endpoints, and evaluate how effects change with fluctuations in the levels (i.e., concentrations) of the various stressors. There are several sources of uncertainty in the assessment of effects on aquatic receptors, including measurement errors, extrapolation errors, and data gaps.

Two types of measurements will be used to evaluate the effects on aquatic receptors that are associated with exposure to COPCs. First, chemical analyses of environmental media will be used, in conjunction with laboratory-derived dose-response relationships and analyses of field-collected data, to evaluate the potential effects on aquatic receptors. These types of measurements are subject to analytical errors and descriptive errors, both of which represent potential sources of uncertainty. Three approaches will be used to address concerns relative to these sources of uncertainty. First, analytical errors will be evaluated using information on the accuracy, precision, and DLs that are generated to support the Phase II sampling program. Second, all data entry, data translation, and data manipulation will be audited to ensure their accuracy. Finally, statistical analyses of resultant data will be conducted to evaluate data distributions, identify the appropriate summary statistics to generate, and evaluate the variability in the observations. Potential measurement errors associated with toxicity tests will be evaluated using negative control results, positive control results, and the results obtained from samples collected in the reference areas.

There are several sources of extrapolation errors in the effects assessment for the Calcasieu Estuary BERA. First, indicator species have been selected to evaluate the potential for exposure effects on certain groups of aquatic receptors. Uncertainties associated with the application of this approach will be evaluated by examining the sensitivities of various species within each group (i.e., using information contained in the USEPA AQUIRE database and elsewhere). These data will be used to develop cumulative distribution functions to evaluate differences in species sensitivities and, hence, the potential implications of using the selected indicator species. In addition, the application of multiple lines of evidence to evaluate effects on assessment endpoints will help to minimize implications associated with this type of extrapolation error. Second, in some cases, the pathways that were selected to evaluate effects on certain receptors were incomplete (i.e., for aquatic plants). Third, in some cases, environmental samples will be collected from areas that may not reflect the conditions that exist in the areas that effects actually occur (e.g., for aquatic plants). The implications of these uncertainties will be described and, to the extent possible, quantified in the uncertainty analysis.

Uncertainty in the exposure and effects assessments for aquatic receptors is also increased by data gaps. To the extent possible, this source of uncertainty will be addressed by collecting comprehensive information on the effects of COPCs in the Calcasieu Estuary. In addition, the use of multiple lines of evidence provides a basis for minimizing the influence of data gaps on the effects assessment. Nevertheless, limitations on certain types of data, such as information on the chemical composition of surface water and the surface microlayer, will necessarily constrain assessments of effects due to direct contact with or ingestion of surface waters, due to direct contact with the surface microlayer, and due to inhalation of COPCs from the surface microlayer. In addition, data were not located on the effects of many COPCs on amphibians or reptiles; therefore, these groups of receptors were not included in the effects assessment for aquatic receptors. The implications of such data gaps, on the results of the risk assessment will be discussed and, to the extent possible, quantified in the uncertainty analysis.

9.3.2 Wildlife Endpoints

Most of the assessments of risks of COPCs to wildlife focal species will rely on one independent line of evidence - comparison of modeled exposures to laboratory-derived effects data. Whole media or *in situ* toxicity tests are not feasible for many of the wildlife species being considered in this assessment (e.g., brown pelican, osprey) because of technical and resource limitations. Comprehensive biological surveys of Calcasieu wildlife over long periods of time have not been conducted. More limited studies, however, are available that can be used to identify the bird and mammal species that occur in the Calcasieu Estuary, their approximate abundance, and the amount of time they spend in the estuary (e.g., year round, migratory, etc.). These studies are not amenable to the kinds of multivariate analyses envisaged for the sediment samples collected for benthic invertebrates because: (1) levels of COPCs in water, sediment and prey were not collected in tandem with the wildlife surveys, and (2) even if such information were available, it would be of limited use because most wildlife species forage widely over space and time thus limiting the utility of local samples of prey tissues or other media.

Relying primarily on one line of evidence means that the wildlife assessments will have sources of uncertainty that cannot be offset by use of other lines of evidence. These sources of uncertainty arise because the comparison of modeled exposures to laboratory-derived effects data involves a number of assumptions and extrapolations:

- The exposure model is assumed to include all major routes of exposure;

- Model inputs are assumed to be reasonable and unbiased;
- Chemical bioavailability in the field and laboratory media are assumed to be similar;
- Differences in field and laboratory environmental conditions are assumed to have no influence on species responses to the COPCs;
- Surrogate species in laboratory bioassays are assumed to have similar sensitivities to wildlife receptors of interest;
- Other stressors (including other chemicals) in the field are assumed to have no influence on responses to the COPC being assessed; and,
- The potential for indirect effects (e.g., COPCs have no effect on wildlife receptor directly, but indirectly causes adverse effects because of a reduction in prey availability) is generally not considered.

Uncertainties about model inputs will be dealt with in the probabilistic wildlife assessments by using distributions to represent key input variables (see Section 9.2.2). The design of the Phase II sampling study should facilitate development of rigorous distributions for the concentrations in fish tissues input variables (i.e., incertitude about the shape and parameterization of these distributions will be low). Further, "what if" analyses (e.g., use of different model equations, or different surrogate species) will be used in the Calcasieu BERA to determine the robustness of the risk estimates. Use of a distributional approach and "what if" analyses represent a significant improvement over deterministic analyses, but there will always be sources of uncertainties (see above list) that cannot be included in a probabilistic risk assessment.

To the extent possible, other lines of evidence will be used to augment the probabilistic risk assessments. For example, many mink feeding studies using fish from contaminated locations have been conducted during the last three decades. The results of these studies incorporate interactions between COPCs and can be used to determine whether such interactions will be important in assessing risks of COPCs to mink in the Calcasieu Estuary. Biological survey information can also be used (to a limited extent) to determine the strength of correspondence between species abundance in the field and results of the probabilistic risk assessment. If, for example, the probabilistic risk assessment predicted severe risks to a wildlife receptor from one or more COPCs, and abundance of the species in contaminated portions of the Calcasieu Estuary was very low (but high elsewhere), then our conclusions about severe risk would be strengthened.

The final strategy for dealing with uncertainties in a risk assessment is to ensure that major assumptions and sources of uncertainty are communicated to risk managers and stakeholders. A variety of tools can be used to assist in this task (see Chapter 3 in Warren-Hicks and Moore 1998). An open and explicit characterization of uncertainty will increase the credibility of the assessment and assure managers and stakeholders that the assessment process is transparent and fair.

Chapter 10 References

Allen, A.W. 1986. Habitat suitability index models: Mink. United States Fish and Wildlife Service Biological Report 82:10-127.

Apple, J., P. del Giorgio, and R. Newell. 2001. Use of microbial community metabolism to assess saltmarsh ecological function. North Carolina National Estuarine Research Reserve Technical Paper Series. Horn Point Laboratory, University of Maryland. Horn Point, Maryland.

ASTM (American Society for Testing and Materials). 2000a. Standard Test Method E1706-00 for measuring the toxicity of sediment-associated contaminants with freshwater invertebrates. *In:* ASTM Annual Book of Standards, Vol. 11.05. West Conshohocken, Pennsylvania.

ASTM (American Society for Testing and Materials). 2000b. Standard Guide E1367-99 for conducting 10-day static sediment toxicity tests with marine and estuarine amphipods. *In:* ASTM Annual Book of Standards, Vol. 11.05. West Conshohocken, Pennsylvania.

ASTM (American Society for Testing and Materials). 2000c. Standard Guide E1688-00 for determination of the bioaccumulation of sediment-associated contaminants by benthic invertebrates. *In:* ASTM Annual Book of Standards, Vol. 11.05. West Conshohocken, Pennsylvania.

Bailer J.A. and J.T. Oris. 1997. Estimating inhibition concentrations for different response scales using generalized linear models. Environmental Toxicology and Chemistry 16:1554-1559.

Bell, P.R. and C.L.F. Woodcock. 1968. The diversity of green plants. Edward Arnold Publishers, Ltd. London, United Kingdom.

Bleavins, M.R., R.J. Aulerich, and R.K. Ringer. 1984. Effects of chronic dietary exposure on the reproductive performance and survivability of mink and European ferrets. Archives of Environmental Contamination and Toxicology 13:357-365.

Brown, S.S., G.R. Gaston, C.F. Rakocinski, and R.W. Heard. 2000. Effects of sediment contaminants and environmental gradients on macrobenthic community trophic structure in Gulf of Mexico estuaries. Estuaries 23:411-424

Burmaster, D.E. and P.D. Anderson. 1994. Principles of good practice for the use of Monte Carlo techniques in human health and ecological risk assessments. Risk Analysis 14:471-481.

Burton, G.A. and B.L. Stemmer. 1988. Evaluation of surrogate tests in toxicant impact assessments. Toxicity Assessment: An International Journal 3:255-269.

Calder W.A. and E.J. Braun. 1983. Scaling of osmotic regulation in mammals and birds. American Journal of Physiology R244:601-606.

Campbell K.R. and T.S. Campbell. 2000. Lizard contaminant data for ecological risk assessment. Reviews of Environmental Contamination and Toxicology 165:39–116.

Carr, R.S. and D.C. Chapman. 1992. Comparison of solid-phase and pore-water approaches for assessing the quality of marine and estuarine sediments. Chemistry and Ecology 7:19-30.

Carr, R.S., E.R. Long, D.C. Chapman, G. Thursby, J.M. Biedenbach, H. Windom, G. Sloane, and D.A. Wolfe. 1996a. Toxicity assessment studies of contaminated sediments in Tampa Bay, Florida. Environmental Toxicology and Chemistry 15:1218-1231.

Carr, R.S., D.C. Chapman, L.C. Howard, and J. Biedenbach. 1996b. Sediment quality triad assessment survey in the Galveston Bay Texas system. Ecotoxicology 5:341-361.

Carr, R.S., D.C. Chapman, B.J. Presley, J.M. Biedenbach, L. Robertson, P. Boothe, R. Kilada, T. Wade, and P. Montagna. 1997. Sediment porewater toxicity assessment studies in the vicinity of offshore oil and gas production platforms in the Gulf of Mexico. Canadian Journal of Fisheries and Aquatic Sciences 53:2618- 2628.

CCME (Canadian Council of Ministers of the Environment). 1996. Threshold Effect Levels (TELs; As cited in CDM 1999).

CCME (Canadian Council of Ministers of the Environment). 1999. Canadian environmental quality guidelines. Guidelines and Standards Division. Environment Canada. Winnipeg, Manitoba.

CDM (CDM Federal Programs Corporation). 1999. Final screening level ecological risk assessment: Calcasieu Estuary, Lake Charles, Louisiana. EPA-68-W5-0022. United States Environmental Protection Agency. Golden, Colorado.

CDM (CDM Federal Programs Corporation). 2000. Technical memorandum. Assessment and measurement endpoints for the ecological risk assessment of the Calcasieu Estuary. Prepared for United States Environmental Protection Agency. Dallas, Texas.

ChemRisk. 1996. Off-site biological inventory evaluation report. ChemRisk Report 1996.05. Prepared for PPG Industries, Inc. Lake Charles, Louisiana. (As cited in McLaren/Hart-ChemRisk 1998).

Choate, J.R., J.K. Jones, Jr., and C. Jones. 1994. Handbook of mammals of the south-central states. Louisiana State University Press. Baton Rouge, Louisiana.

Colinvaux, P.A. 1973. Introduction to ecology. John Wiley and Sons, Inc. New York, New York.

Conant, R. and J.T. Collins. 1998. A field guide to reptiles and amphibians, Eastern and Central North America, third edition. Houghton Mifflin Company. New York, New York.

Covello, V.T. and M.W. Merkhofer. 1993. Risk assessment methods: Approaches for assessing health and environmental risks. Plenum Press. New York, New York.

Cullen, A.C. and H.C. Frey. 1999. Probabilistic techniques in exposure assessment. Plenum Press. New York, New York.

Curry, M.S., M.T. Huguenin, A.J. Martin, and T.R. Lookingbill. 1997. Contamination extent report and preliminary injury evaluation for the Calcasieu Estuary. Prepared by Industrial Economics, Incorporated. Prepared for National Oceanic and Atmospheric Administration. Silver Spring, Maryland.

DeRouen, L.R., R.W. Hann, D.M. Casserly, C.Giammona, and V.J. Lascara (Eds.). 1983. West Hackberry strategic petroleum reserve site brine disposal monitoring. Final report. Volumes 1 - 3. Department of Energy Contract Number DE-AC96-80P010288. McNeese State University. Lake Charles, Louisiana. (As cited in Felley 1987b).

Dundee, H.A. and D.A. Rossman. 1996. The amphibians and reptiles of Louisiana. Louisiana State University Press. Baton Rouge, Louisiana.

EC (Environment Canada). 1998. Interim sediment quality guidelines. Draft. January 1998. (As cited in CDM 1999.)

Felley, J.D. 1987a. Nekton assemblages of three tributaries to the Calcasieu Estuary, Louisiana. Estuaries 10(4):321-329.

Felley, J.D. 1987b. Nekton assemblages of the Calcasieu River/Lake complex. *In:* Ecosystem Analysis of the Calcasieu River/Lake Complex (CALECO). L.R. DeRouen and L.H. Stevenson (Eds.). McNeese State University. Lake Charles, Louisiana. pp. 6-1 to 6-91.

Felley, J.D. and S.M. Felley. 1986. Habitat partitioning of fishes in an urban estuarine bayou. Estuaries 9:208-218. (As cited in Felley 1987b).

Ferson, S. and M. Burgman. 1995. Correlations, dependency bounds and extinction risks. Biological Conservation 73:101-105.

Field, L.J., D.D. MacDonald, S.B. Norton, C.G. Ingersoll, C.G. Severn, D.E. Smorong, and R.A. Lindskoog. *In review*. Predicting amphipod toxicity from sediment chemistry using logistic regression models. Submitted to Environmental Toxicology and Chemistry (September 2001).

Finkel, A.M. 1990. Confronting uncertainty in risk management. A guide for decision-makers. Center for Risk Management, Resources for the Future. Washington, District of Columbia.

Gaston, G.R. 1987a. Trophic structure of macrobenthic communities in the Calcasieu River/Lake complex. *In:* Ecosystem Analysis of the Calcasieu River/Lake Complex (CALECO). L.R. DeRouen and L.H. Stevenson (Eds.). McNeese State University. Lake Charles, Louisiana. pp. 5C-1 to 5C-55.

Gaston, G.R. 1987b. Trophic structure of estuarine macrobenthos in Calcasieu Lake, Louisiana. *In:* Ecosystem Analysis of the Calcasieu River/Lake Complex (CALECO). L.R. DeRouen and L.H. Stevenson (Eds.). McNeese State University. Lake Charles, Louisiana. 5B-1 to 5B-34.

Gaston, G.R. and J.C. Nasci. 1988. Trophic structure of macrobenthic communities in the Calcasieu Estuary, Louisiana. Estuaries 11(30):201-211.

Gaston, G.R. and J.C. Young. 1992. Effects of contaminants on macrobenthic communities in the upper Calcasieu estuary, Louisiana. Bulletin of Environmental Contamination and Toxicology 49:922-928.

Gaston, G.R., D.L. Lee, and J.C. Nasci. 1988. Estuarine macrobenthic in Calcasieu Lake, Louisiana: Community and trophic structure. Estuaries 11(3):192-200.

Goldberg, M. 2001. Summary of the scoping meeting for refining the list of contaminants of potential concern in the Calcasieu Estuary. CDM Federal Programs Corporation. Dallas, Texas.

Gottschang, J.L. 1981. A guide to the mammals of Ohio. Ohio State University Press, Columbus, Ohio.

Haimes, Y.Y., T. Barry and J.H. Lambert (eds.). 1994. When and how can you specify a probability distribution when you don't know much? Risk Analysis 14:661-706.

Hattis, D. and D.E. Burmaster. 1994. Assessment of variability and uncertainty distributions for practical risk analyses. Risk Analysis 14:713-730.

Herke, W.H., B.D. Rogers, and J.A. Grimes. 1984. Sabine fisheries study. Volumes 1 - 3. Louisiana Cooperative Fishery Research Unit. Louisiana State University. Baton Rouge, Louisiana. (As cited in Felley 1987b).

Hoese, H.D. and R.H. Moore. 1998. Fishes of the Gulf of Mexico: Texas, Louisiana, and Adjacent Waters, Second Edition. Texas A&M University Press. College Station, Texas.

Hoffman, F.O. and J.S. Hammonds. 1994. Propagation of uncertainty in risk assessments: The need to distinguish between uncertainty due to lack of knowledge and uncertainty due to variability. Risk Analysis 14:707-712.

Hooten R.L. and R.S. Carr. 1998. Development and application of a marine sediment porewater toxicity test using *Ulva fasciata* and *U. lactuca* zoospores. Environmental Toxicology and Chemistry 17:932-940.

InfoLouisiana. 2001. Entry to state government information and services. http://www.state.la.us. Web page accessed on May 22, 2001.

Johnson, B.T. 1998. Microtox toxicity test system: New developments and applications. *In:* Microscale testing in aquatic toxicology. P.G. Wells, K. Lee, and C. Blaise (Eds.). pp. 201-215.

Johnson B.T. and E.R. Long. 1998. Rapid toxicity assessment of sediments from large estuarine ecosystems: A new tandem *in vitro* testing approach. Environmental Toxicology and Chemistry 17:1099-1106.

Kerr D.R. and J.P. Meador. 1996. Modeling dose response using generalized linear models. Environmental Toxicology and Chemistry 15:395-401.

LDEC (Louisiana Department of Conservation). 1931. The birds of Louisiana. Louisiana Department of Conservation, Bulletin No. 20. New Orleans, Louisiana.

LDEQ (Louisiana Department of Environmental Quality). 1998a. Louisiana water quality criteria. LR24:688. Office of Water Resources. Baton Rouge, Louisiana.

LDEQ (Louisiana Department of Environmental Quality). 1998b. Louisiana water quality criteria. Promulgated by LDEQ, LR 10:745 (October 1984) in accordance with R .S. 30:2074(B)(1), amended LR 15:738 (September 1989), LR 17:264 (March 1991), LR 17:967 (October 1991), repromulgated LR 17:1083 (November 1991), amended LR 20:883 (August 1994), LR 24:688 (April 1998). Office of Water Resources. (As cited in CDM 1999.)

LDWF (Louisiana Department of Fish and Wildlife). 2001. Nongame Programs, Threatened & Endangered Species. http://www.wlf.state.la.us. Web page accessed on May 23, 2001.

Long, E.R. and L.G. Morgan. 1991. The potential for biological effects of sediment-sorbed contaminants tested in the National Status and Trends Program. NOAA Technical Memorandum NOS OMA 52. National Oceanic and Atmospheric Administration. Seattle, Washington. pp. 175 + appendices.

Long, E.R. and D.D. MacDonald. 1998. Recommended uses of empirically derived, sediment quality guidelines for marine and estuarine ecosystems. Human and Ecological Risk Assessment 4:1019-1039.

Long, E.R., D.D. MacDonald, S.L. Smith, and F.D. Calder. 1995. Incidence of adverse biological effects within ranges of chemical concentrations in marine and estuarine sediments. Environmental Management 19:81-97.

Louisiana Ornithological Society, Inc. 2001. Checklist of Louisiana birds. http://www.losbird.org/checklist.htm. Web page accessed on May 28, 2001.

Lowery, G.H., Jr. 1974. The mammals of Louisiana and its adjacent waters. Published for the Louisiana Wildlife and Fisheries Commission, Louisiana State University Press. Kingsport Press, Inc. Kingsport, Tennessee.

MacDonald, D.D., R.S. Carr, F.D. Calder, E.R. Long, and C.G. Ingersoll. 1996. Development and evaluation of sediment quality guidelines for Florida coastal waters. Ecotoxicology 5:253-278.

MacDonald, D.D., C.G. Ingersoll, D. Moore, and R.S. Carr. 2000a. Calcasieu Estuary remedial investigation/feasibility study (RI/FS): Baseline Ecological Risk Assessment workshop, workshop summary report. Report prepared for CDM Federal Programs Corporation. Dallas, Texas.

MacDonald, D.D., C.G. Ingersoll, and T.A. Berger. 2000b. Development and evaluation of consensus-based sediment quality guidelines for freshwater ecosystems. Archives of Environmental Contamination and Toxicology 39:20-31.

MacDonald, D.D. and C.G. Ingersoll. 2001. A guidance manual to support the assessment of contaminated sediments in the Great Lakes Basin. Preliminary draft, technical report. Prepared for the Great Lakes National Program Office, United States Environmental Protection Agency. Nanaimo, British Columbia.

Maples, R.S. 1987a. Checklist of phytoplankton for the Calcasieu River/Lake complex. *In:* Ecosystem Analysis of the Calcasieu River/Lake Complex (CALECO). L.R. DeRouen and L.H. Stevenson (Eds.). McNeese State University. Lake Charles, Louisiana. pp. 3B-1 to 3B-8.

Maples, R.S. 1987b. Phytoplankton ecology of Calcasieu Lake, Louisiana. *In:* Ecosystem Analysis of the Calcasieu River/Lake Complex (CALECO). L.R. DeRouen and L.H. Stevenson (Eds.). McNeese State University. Lake Charles, Louisiana. pp. 3E-1 to 3E-39.

Maples, R.S. 1987c. Diatoms as indicators of water quality in three bayous of the Calcasieu River/Lake complex. *In:* Ecosystem Analysis of the Calcasieu River/Lake Complex (CALECO). L.R. DeRouen and L.H. Stevenson (Eds.). McNeese State University. Lake Charles, Louisiana. pp. 3C-1 to 3C-17.

Maples, R.S. 1987d. Bluegreen algae as indicators of eutrophication in three bayous of the Calcasieu River/Lake complex. *In:* Ecosystem Analysis of the Calcasieu River/Lake Complex (CALECO). L.R. DeRouen and L.H. Stevenson (Eds.). McNeese State University. Lake Charles, Louisiana. pp. 3D-1 to 3D-10.

McLaren/Hart-ChemRisk. 1998. Off-site ecological risk assessment for the PPG-Lake Charles facility. Volume I. Prepared for PPG Industries, Inc. Lake Charles, Louisiana.

Meyers-Schöne, L. 2000. Ecological risk assessment of reptiles. *In:* Ecotoxicology of amphibians and reptiles. Sparling, D.W., G. Linder, and C.A. Bishop (Eds.). SETAC Press. Pensacola, Florida. pp. 793–810.

Moore D.R.J., R.L. Breton, and K. Lloyd. 1997. The effects of hexachlorobenzene on mink in the Canadian environment: An ecological risk assessment. Environmental Toxicology and Chemistry 16:1042-1050.

Moore D.R.J., B.E. Sample, G.W. Suter, B.R. Parkhurst, and R.S. Teed. 1999a. Risk-based decision making: A case study for piscivores exposed to contaminants at East Fork Poplar Creek, Oak Ridge, Tennessee. Environmental Toxicology and Chemistry 18:2954-2958.

Moore D.R.J., B.E. Sample, G.W. Suter, B.R. Parkhurst, and R.S. Teed. 1999b. A probabilistic risk assessment of the effects of methylmercury and PCBs on mink and kingfishers along East Fork Poplar Creek, Oak Ridge, Tennessee. Environmental Toxicology and Chemistry 18:2941-2953.

Moore, D.R.J., W.J. Warren-Hicks, B.R. Parkhurst, R.S. Teed, R.B. Baird, R. Berger, D.L. Denton and J.J. Pletl. 2000. Intra- and inter-treatment variance in reference toxicant tests. Environmental Toxicology and Chemistry 19:105-112.

Morgan, M.G. and M. Henrion. 1990. Uncertainty: A guide to dealing with uncertainty in quantitative risk and policy analysis. Cambridge University Press. Cambridge, United Kingdom.

Nagy, K.A. 1987. Field metabolic rate and food requirement scaling in mammals and birds. Ecological Monographs 57:111-128.

NOAA (National Oceanic and Atmospheric Administration). 1997. Screening Quick Reference Tables (SQRTs). Haxmat Report 97-2. (As cited in CDM 1999.)

Odum, E.P. 1975. Ecology: The link between the natural and the social sciences. Second Edition. Modern Biology Series. Holt, Rinehart, and Winston. New York, New York.

Perret, W.S., B.B. Barrett, W.R. Latapie, J.F. Pollard, W.R. Mock., G.B. Adkins, W.J. Gaidry, and C.J. White. 1970. Cooperative Gulf of Mexico estuarine inventory and study, Louisiana. Phase I: Area description. Louisiana Wildlife and Fisheries Commission. New Orleans, Louisiana.

PRC (TetraTech EMI). 1994. Site inspection for Bayou Verdine. Prepared for Conoco. Lake Charles, Louisiana.

Ramelow, G.J., C. Webre, C.S. Mueller, J.N. Beck, J. Young, and M.P. Langley. 1987. Variations of heavy metals in fish and other organisms from the Calcasieu River/Lake complex. *In:* Ecosystem Analysis of the Calcasieu River/Lake Complex (CALECO). L.R. DeRouen and L.H. Stevenson (Eds.). McNeese State University. Lake Charles, Louisiana. pp. 2H-1 to 2H-34.

Reynoldson T.B., K.E. Day, R.C. Bailey, and R.H. Norris. 1995. Methods for establishing biologically based sediment guidelines for freshwater quality management using benthic assessment of sediment. Australian Journal of Ecology 20:198-219.

Robbins, C.S., B. Bruun, and H.S. Zim. 1983. A guide to field identification, birds of North America. Golden Press. New York, New York.

Rush, G.F., J.H. Smith, K. Maita, M. Bleavins, R.J. Aulerich, R.K. Ringer, and J.B. Hook. 1983. Perinatal hexachlorobenzene toxicity in the mink. Environmental Research 31:116-124.

Sample, B.E. and D.M. Opresko. 1996. Toxicological benchmarks for wildlife: 1996 revision. ES/ER/TM-86/R3. Oak Ridge National Laboratory. Oak Ridge, Tennessee.

Sample, B., D. Opresko, and G. Suter II. 1996. Toxicological benchmarks for wildlife: 1996 Revision. ES/ER/TM-86/R3. Prepared by the Risk Assessment Program, Health Sciences Research Division, Oak Ridge, Tennessee. Prepared for the United States Department of Energy. (As cited in CDM 1999.)

Suter II, G.W., B.E. Sample, D.S. Jones, T.L. Ashwood, and J.M. Loar. 1995. Approach and strategy for performing ecological risk assessments for the United States Department of Energy's Oak Ridge Reservation. ES/ER/TM-33/R2. Oak Ridge National Laboratory. Oak Ridge, Tennessee.

Suter II, G.W. 1996. Risk characterization for ecological risk assessment of contaminated sites. ES/ER/TM-200. Oak Ridge National Laboratory. Oak Ridge, Tennessee.

Suter II, G.W. 1997. A framework for assessing ecological risks of petroleum-derived materials in soils. Environ. Sci. Div. Publ. No.4666. Oak Ridge National Laboratory. Oak Ridge, Tennessee.

Texas Natural Resource Conservation Commission (TNRCC). 2000. Guidance for conducting ecological risk assessments at remediation sites in Texas. Final Draft. Austin, Texas.

Thompson, B.A. and G.R. Fitzhugh. 1986. A use attainability study: An evaluation of fish and macroinvertebrates of the lower Calcasieu River, Louisiana. Office of Water Resources. Louisiana Department of Environmental Quality. Baton Rouge, Louisiana. (As cited in Felley 1987b).

USEPA (United States Environmental Protection Agency). 1985. Quantification of toxicological effects of 1,2-dichloroethane. Office of Drinking Water. Washington, District of Columbia.

USEPA (United States Environmental Protection Agency). 1989. Risk assessment guidance for superfund, volume II, environmental evaluation manual. Interim final. EPA-540/1-89/001. Office of Solid Waste and Emergency Response. Washington, District of Columbia.

USEPA (United States Environmental Protection Agency). 1992. Framework for ecological risk assessment. EPA/630/R-92-001. Office of Solid Waste and Emergency Response. Washington, District of Columbia.

USEPA (United States Environmental Protection Agency). 1993. Wildlife exposure factors handbook. Volumes I and II. EPA/600/R-93/187a&b. Office of Health and Environmental Assessment. Office of Research and Development. Washington, District of Columbia.

USEPA (United States Environmental Protection Agency). 1997a. Ecological risk assessment guidance for Superfund: Process for designing and conducting ecological risk assessments. Environmental Response Team. Edison, New Jersey.

USEPA (United States Environmental Protection Agency). 1997b. Guiding principles for Monte Carlo analysis. EPA/630/R-97/001. Office of Research and Development. Washington, District of Columbia.

USEPA (United States Environmental Protection Agency). 1998a. Guidelines for ecological risk assessment. Risk Assessment Forum. EPA/630/R-95/002F. Washington, District of Columbia.

USEPA (United States Environmental Protection Agency). 1998b. National recommended water quality criteria. Publication 68354 Federal Register / Vol. 63, No. 237 / Thursday, December 10, 1998 / Notices. (As cited in CDM 1999).

USEPA (United States Environmental Protection Agency). 1999a. National recommended water quality criteria - correction. EPA-822-Z-99-001. Office of Water. Washington, District of Columbia.

USEPA (United States Environmental Protection Agency). 1999b. Risk assessment guidance for Superfund: Volume 3 - Part A, process for conducting probabilistic risk assessment. Draft. Office of Solid Waste and Emergency Response. Washington, District of Columbia.

USEPA (United States Environmental Protection Agency). 2000a*. Envirofacts Data Warehouse and Applications, Water Discharge Permits (PCS database) (http://www.epa.gov/enviro/index_java.html). Web page accessed on August 21, 2001. * date of last web page update; PCS database creation/revision date unknown.

USEPA (United States Environmental Protection Agency). 2000b. Stressor identification guidance document. EPA-822-B-00-025. Office of Water. Office of Research and Development. Washington, District of Columbia.

USEPA (United States Environmental Protection Agency). 2000c. Prediction of sediment toxicity using consensus-based freshwater sediment quality guidelines. EPA 905/R-00/007. Great Lakes Program Office. Chicago, Illinois.

USEPA (United States Environmental Protection Agency). 2000d. Methods for measuring the toxicity and bioaccumulation of sediment-associated contaminants with freshwater invertebrates. Second edition. EPA 600/R-99/064. Washington, District of Columbia.

USFWS (United States Fish and Wildlife Service). 2001a. ESA Basics, over 25 years of protecting endangered species. Endangered Species Program. Arlington, Virginia.

USFWS (United States Fish and Wildlife Service). 2001b. Conserving Wildlife and Habitat, Endangered Species. http://www.endangered.fws.gov. Web page accessed May 23, 2001.

Vecchione, M. 1987. Zooplankton distribution in the Calcasieu River/Lake complex. *In:* Ecosystem Analysis of the Calcasieu River/Lake Complex (CALECO). L.R. DeRouen and L.H. Stevenson (Eds.). McNeese State University. Lake Charles, Louisiana. pp. 4D-1 to 4D-18.

Warren-Hicks, W.J. and D.R.J. Moore (Eds.). 1998. Uncertainty analysis in ecological risk assessment. SETAC Press. Pensacola, Florida.

Watson, R. 2001. Letter to John Meyer. United States Environmental Protection Agency, Region 6 regarding federally listed threatened, endangered, or candidate species in the Calcasieu Estuary study area. United States Fish and Wildlife Service. Lafayette, Louisiana. 3 pp.

Wetzel, R.G. 1983. Limnology. Second Edition. Saunders College Publishing. Harcourt Brace College Publishers. Fort Worth, Texas.

Tables

Table 3.1. Summary of contaminants that have been released into surface waters from various industrial facilities (abstracted from Curry *et al.* 1997).

	Upper Calcasieu			Bayou d'Inde					Middle	
Substance	**Conoco**	**Vista**	**Olin**	**PPG**	**OxyChem**	**Westlake**	**Firestone**	**Citgo**	**Citgo**	**W.R. Grace**
Metals										
Arsenic			✓							
Cadmium					✓			✓	✓	✓
Chromium		✓				✓		✓	✓	
Copper		✓		✓		✓				
Lead		✓		✓						
Mercury				✓						
Nickel		✓	✓	✓						✓
Zinc	✓	✓	✓	✓		✓	✓			✓
SVOCs										
BTX		✓			✓			✓	✓	
PAHs	✓				✓			✓	✓	
Phthalates	✓		✓	✓	✓	✓	✓			
HCB/HCBD				✓						
Phenols	✓							✓	✓	
VOCs		✓	✓	✓		✓		✓	✓	
TCA				✓						
DCE	✓	✓	✓	✓	✓					
Acetone						✓				
Petroleum Hydrocarbons										
Oil	✓		✓		✓	✓	✓	✓	✓	
Kerosene	✓	✓								
Diesel	✓									
Naphtha	✓									
Chlorinated Hydrocarbons				✓						

SVOCs = Semi-volatile organic compounds; BTX = Benzene, toluene, xylene; PAHs = Polycyclic aromatic hydrocarbons; HCB/HCBD = Hexachlorobenzene/hexachlorobutadiene; VOCs = Volatile organic compounds; TCA = Trichloroethane; DCE = Dichloroethane.

Table 3.2. Releases of contaminants from industrial sources to waterbodies within the Calcasieu Estuary (from CDM 1999).

Waterbody	Potential Source(s)[1]	Substances[2]
Bayou d'Inde	PPG (chlorinated hydrocarbon manufacturing process)	Hexachlorobenzene, Hexachlorobutadiene, Hexachlorocyclopentadiene, Hexachloroethane, Dichlorobenzene, Trichloroethene, 1,2,4-Trichlorobenzene, and Vinyl chloride
Bayou d'Inde	Bayou d'Inde industrial complex (includes Citgo, Firestone, OxyChem, and Westlake)	Xylene, Methyl naphthalene, and Di-n-butylphthalate
Bayou Verdine	Vista (via western discharge ditch)	Chloroethane, Chloroform, 1,2-Dichloroethane, Vinyl chloride, Fluoranthene, and Phenanthrene
Bayou Verdine	Conoco (refinery processes)	Chloroform, 1,2-Dichloroethane, Fluoranthene, Phenanthrene, Xylene, Tetrachloroethene, Toluene, Dibenz[a,h]anthracene, Dibenzofuran, Naphthalene, Bromoform, Diesel, and Gasoline
Coon Island Loop	Conoco (refinery processes), PPG (solid waste management units and groundwater)	Chloroform, 1,2-Dichloroethane, Fluoranthene, Phenanthrene, Xylene, Tetrachloroethene, Toluene, Dibenz[a,h]anthracene, Dibenzofuran, Naphthalene, Bromoform, Diesel, and Gasoline
Prien Lake	Conoco and PPG (via Bayou d'Inde and Coon Island Loop)	Hexachlorobenzene, Hexachlorobutadiene, Hexachlorocyclopentadiene, Hexachloroethane, Dichlorobenzene, Trichloroethene, 1,2,4-Trichlorobenzene, Vinyl chloride, Chloroform, 1,2-Dichloroethane, Fluoranthene, Phenanthrene, Xylene, Tetrachloroethene, Toluene, Dibenz[a,h]anthracene, Dibenzofuran, Naphthalene, Bromoform, Diesel, and Gasoline

[1]Results of the ongoing remedial investigation and source studies by EPA Region VI may identify additional chemicals and other potential sources.

[2]List is not comprehensive.

Table 3.3. Calculation of hazard quotients and selection of preliminary contaminants of potential concern (estuary-wide surface water data; from CDM 1999).

Chemical	Maximum Detected Concentration	Maximum Detection Limit	Units	Detection Frequency	Exposure Point Concentration (1)	Units	Freshwater Ecological Screening Value (2)	Marine Ecological Screening Value (2)	Lowest Ecological Screening Value (3)	COPC Flag	Rationale for Contaminant Deletion or Selection	Hazard Quotient EPC / ESV
1,1,1-Trichloroethane	14	10	µg/l	3/96	14	µg/l	2640	1560	1560	NO	BSL	0.01
1,1,2,2-Tetrachloroethane	5	10	µg/l	4/96	5	µg/l	466	451	451	NO	BSL	0.01
1,1,2-Trichloroethane	17	10	µg/l	10/96	17	µg/l	900	0	900	NO	BSL	0.02
1,1-Dichloroethane	1	10	µg/l	1/96	1	µg/l	0	0	0	YES*	NSL,D	0
1,1-Dichloroethene	2	10	µg/l	1/96	2	µg/l	580	11,200	580	NO	BSL	0.003
1,2-Dichloroethane	140	10	µg/l	49/96	140	µg/l	5900	5650	5650	NO	BSL	0.02
1,2-Dichloroethene, total	1	10	µg/l	1/82	1	µg/l	0	0	0	YES*	NSL,D	0
2-Butanone	8	100	µg/l	3/96	8	µg/l	0	0	0	YES*	NSL,D	0
2-Hexanone	7	50	µg/l	1/92	7	µg/l	0	0	0	YES*	NSL,D	0
4-Methyl-2-pentanone	8	50	µg/l	1/92	8	µg/l	0	0	0	YES*	NSL,D	0
Acetone	38	50	µg/l	7/96	38	µg/l	0	0	0	YES*	NSL,D	0
Alkalinity	201	NA	mg/l	38/38	201	mg/l	0	0	0	YES*	NSL,D	0
Aluminum	2000	42	µg/l	68/132	2000	µg/l	0	0	0	YES*	NSL,D	0
Antimony	9.4	22	µg/l	15/128	9	µg/l	0	0	0	YES*	NSL,D	0
Arsenic	12.4	40	µg/l	12/132	12	µg/l	150	36	36	NO	BSL	0.34
Barium	206	NA	µg/l	132/132	206	µg/l	0	0	0	YES*	NSL,D	0
Beryllium	1.3	15	µg/l	2/132	1.3	µg/l	0	0	0	YES*	NSL,D	0
Biochemical oxygen demand	7600	NA	µg/l	217/217	7600	µg/l	0	0	0	YES*	NSL,D	0
Bromoform	29	10	µg/l	19/96	29	µg/l	1465	895	895	NO	BSL	0.03
Cadmium	1.2	4	µg/l	1/132	1.2	µg/l	0.66	9.3	0.66	YES	ASL	1.8
Calcium	227000	NA	µg/l	132/132	227000	µg/l	0	0	0	NO	NA	0
Carbon disulfide	52	10	µg/l	3/96	52	µg/l	0	0	0	YES*	NSL,D	0
Chloride	10247	NA	µg/l	63/63	10247	µg/l	0	0	0	YES*	NSL,D	0
Chlorine, total	0.26	0.01	µg/l	170/182	0.26	µg/l	0	0	0	YES*	NSL,D	0
Chloroform	33	10	µg/l	19/96	33	µg/l	1445	4075	1445	NO	BSL	0.02
Chromium	10	6	µg/l	1/132	10	µg/l	74	103	74	NO	BSL	0.14
Conductivity	212649	NA	umhos/	2378/2378	212649	umhos/	0	0	0	YES*	NSL,D	0
Copper	23.9	6.2	µg/l	19/132	24	µg/l	7.1	3.1	3.1	YES	ASL	7.7
Cyanide	2.9	1	µg/l	3/15	3	µg/l	5.2	1	1	YES	ASL	2.9
Di-n-butylphthalate	14	50	µg/l	5/69	14	µg/l	0	0	0	YES*	NSL,D	0
Dibromochloromethane	7	10	µg/l	8/96	7	µg/l	0	0	0	YES*	NSL,D	0
Diesel range organics	3.6	0.18	mg/l	6/63	4	mg/l	0	0	0	YES*	NSL,D	0
Diethylphthalate	11	50	µg/l	7/65	11	µg/l	0	0	0	YES*	NSL,D	0

Table 3.3. Calculation of hazard quotients and selection of preliminary contaminants of potential concern (estuary-wide surface water data; from CDM 1999).

Chemical	Maximum Detected Concentration	Maximum Detection Limit	Units	Detection Frequency	Exposure Point Concentration (1)	Units	Freshwater Ecological Screening Value (2)	Marine Ecological Screening Value (2)	Lowest Ecological Screening Value (3)	COPC Flag	Rationale for Contaminant Deletion or Selection	Hazard Quotient EPC / ESV
Dimethylphthalate	0.7	50	µg/l	1/83	1	µg/l	0	0	0	YES*	NSL,D	0
Dissolved oxygen	19.61	0.05	mg/l	2274/2339	20	mg/l	0	0	0	YES*	NSL,D	0
Dissolved oxygen saturation	59	NA	%	12/12	59	%	0	0	0	YES*	NSL,D	0
Hardness, total	4330	NA	mg/l	143/143	4330	mg/l	0	0	0	YES*	NSL,D	0
Hexachlorobutadiene	3	50	µg/l	1/83	3	µg/l	1.02	0.32	0.32	YES	ASL	9.4
Iron	1740	5	µg/l	100/132	1740	µg/l	0	0	0	YES*	NSL,D	0
Lead	32.8	5	µg/l	35/124	33	µg/l	1.3	8.1	1.3	YES	ASL	25.2
Magnesium	4590000	NA	µg/l	132/132	4590000	µg/l	0	0	0	NO	NA	0
Manganese	698	0.5	µg/l	125/131	698	µg/l	0	0	0	YES*	NSL,D	0
Methylene Chloride	6	10	µg/l	8/96	6	µg/l	9650	12800	9650	NO	BSL	0.001
Nickel	12.9	15	µg/l	14/132	13	µg/l	52	8.2	8.2	YES	ASL	1.6
Nitrate	0.26	0.05	mg/l	23/63	0.26	mg/l	0	0	0	YES*	NSL,D	0
Nitrite	0.09	0.05	mg/l	21/63	0.09	mg/l	0	0	0	YES*	NSL,D	0
Nitrogen, ammonia	9.88	0.05	mg/l	271/282	10	mg/l	0	0	0	YES*	NSL,D	0
Potassium	231000	NA	µg/l	132/132	231000	µg/l	0	0	0	YES*	NSL,D	0
Salinity	35.1	0.1	ppt	2334/2348	35	ppt	0	0	0	YES*	NSL,D	0
Secchi depth	4.9	NA	ft	129/129	5	ft	0	0	0	YES*	NSL,D	0
Selenium	33	30	µg/l	8/117	33	µg/l	5	71	5	YES	ASL	6.6
Silver	4.1	4	µg/l	1/132	4	µg/l	3.4	1.9	1.9	YES	ASL	2.2
Sodium	5810000	NA	µg/l	132/132	5810000	µg/l	0	0	0	NO	NA	0
Sulfate	1574	NA	mg/l	63/63	1574	mg/l	0	0	0	YES*	NSL,D	0
Temperature	37.97	NA	degree	2380/2380	38	degree	0	0	0	YES*	NSL,D	0
Tetrachloroethene	6	10	µg/l	3/96	6	µg/l	645	510	510	NO	BSL	0.01
Thallium	61	40	µg/l	32/128	61	µg/l	0	0	0	YES*	NSL,D	0
Toluene	2	10	µg/l	1/96	2	µg/l	635	475	475	NO	BSL	0.004
Total dissolved solids	19130	NA	mg/l	63/63	19130	mg/l	0	0	0	YES*	NSL,D	0
Total organic carbon	16.5	1	mg/l	8/38	17	mg/l	0	0	0	YES*	NSL,D	0
Total organic carbon, filtered	5.9	NA	mg/l	72/72	6	mg/l	0	0	0	YES*	NSL,D	0
Total organic carbon, unfiltered	25	NA	mg/l	107/107	25	mg/l	0	0	0	YES*	NSL,D	0
Total suspended solids	83	NA	mg/l	145/145	83	mg/l	0	0	0	YES*	NSL,D	0
Trichloroethene	4	10	µg/l	1/96	4	µg/l	1950	100	100	NO	BSL	0.04
Turbidity	412	0.1	ntu	1237/1271	412	ntu	0	0	0	YES*	NSL,D	0
Vanadium	5.9	25	µg/l	6/132	5.9	µg/l	0	0	0	YES*	NSL,D	0

Table 3.3. Calculation of hazard quotients and selection of preliminary contaminants of potential concern (estuary-wide surface water data; from CDM 1999).

Chemical	Maximum Detected Concentration	Maximum Detection Limit	Units	Detection Frequency	Exposure Point Concentration (1)	Units	Freshwater Ecological Screening Value (2)	Marine Ecological Screening Value (2)	Lowest Ecological Screening Value (3)	COPC Flag	Rationale for Contaminant Deletion or Selection	Hazard Quotient EPC / ESV
Vinyl chloride	4	10	µg/l	1/96	4	µg/l	0	0	0	YES*	NSL,D	0
Zinc	358	16.25	µg/l	79/132	358	µg/l	59	81	59	YES	ASL	6.1
Bis(2-chloroethyl)ether	5	50	µg/l	11/83	5	µg/l	0	0	0	YES*	NSL,D	0
Bis(2-ethylhexyl)phthalate	94	10	µg/l	9/69	94	µg/l	0	0	0	YES*	NSL,D	0
Gamma-chlordane	0.018	0.05	µg/l	1/69	0.02	µg/l	0.0043	0.004	0.004	YES	ASL	4.50
pH	8.71	NA	units	1984/1984	8.7	units	0	0	0	YES*	NSL,D	0
1,2,4-Trichlorobenzene	NA	50	µg/l	0/83	50	µg/l	0	0	0	NO*	NSL,ND	0
1,2-Dichlorobenzene	NA	50	µg/l	0/83	50	µg/l	0	0	0	NO*	NSL,ND	0
1,2-Dichloropropane	NA	10	µg/l	0/92	10	µg/l	0	0	0	NO*	NSL,ND	0
1,3-Dichlorobenzene	NA	50	µg/l	0/83	50	µg/l	0	0	0	NO*	NSL,ND	0
1,4-Dichlorobenzene	NA	50	µg/l	0/83	50	µg/l	0	0	0	NO*	NSL,ND	0
2,4,5-Trichlorophenol	NA	120	µg/l	0/79	120	µg/l	0	0	0	NO*	NSL,ND	0
2,4,6-Trichlorophenol	NA	50	µg/l	0/79	50	µg/l	0	0	0	NO*	NSL,ND	0
2,4-Dichlorophenol	NA	50	µg/l	0/79	50	µg/l	101	0	101	NO	BSL	0.50
2,4-Dimethylphenol	NA	50	µg/l	0/79	50	µg/l	0	0	0	NO*	NSL,ND	0
2,4-Dinitrophenol	NA	120	µg/l	0/65	120	µg/l	0	0	0	NO*	NSL,ND	0
2,4-Dinitrotoluene	NA	50	µg/l	0/65	50	µg/l	0	0	0	NO*	NSL,ND	0
2,6-Dinitrotoluene	NA	50	µg/l	0/79	50	µg/l	0	0	0	NO*	NSL,ND	0
2-Chloronaphthalene	NA	50	µg/l	0/79	50	µg/l	0	0	0	NO*	NSL,ND	0
2-Chlorophenol	NA	50	µg/l	0/79	50	µg/l	129	0	129	NO	BSL	0.39
2-Methylnaphthalene	NA	50	µg/l	0/83	50	µg/l	0	0	0	NO*	NSL,ND	0
2-Methylphenol	NA	50	µg/l	0/83	50	µg/l	0	0	0	NO*	NSL,ND	0
2-Nitroaniline	NA	120	µg/l	0/79	120	µg/l	0	0	0	NO*	NSL,ND	0
2-Nitrophenol	NA	50	µg/l	0/79	50	µg/l	0	0	0	NO*	NSL,ND	0
3,3'-Dichlorobenzidine	NA	50	µg/l	0/65	50	µg/l	0	0	0	NO*	NSL,ND	0
3-Nitroaniline	NA	120	µg/l	0/79	120	µg/l	0	0	0	NO*	NSL,ND	0
4,4'-Dichlorodiphenyldichloroethane (DDD)	NA	0.1	µg/l	0/69	0.1	µg/l	0.006	0.25	0.006	YES	ASL	16.7
4,4'-Dichlorodiphenyldichloroethene (DDE)	NA	0.1	µg/l	0/69	0.1	µg/l	10.5	0.14	0.14	NO	BSL	0.71
4,4'-Dichlorodiphenyltrichloroethane (DDT)	NA	0.1	µg/l	0/65	0.1	µg/l	0.001	0.001	0.001	YES	ASL	100
4,6-Dinitro-2-methylphenol	NA	120	µg/l	0/65	120	µg/l	0	0	0	NO*	NSL,ND	0
4-Bromophenyl-phenylether	NA	50	µg/l	0/69	50	µg/l	0	0	0	NO*	NSL,ND	0
4-Chloro-3-methylphenol	NA	50	µg/l	0/79	50	µg/l	0	0	0	NO*	NSL,ND	0
4-Chloroaniline	NA	50	µg/l	0/79	50	µg/l	0	0	0	NO*	NSL,ND	0

Table 3.3. Calculation of hazard quotients and selection of preliminary contaminants of potential concern (estuary-wide surface water data; from CDM 1999).

Chemical	Maximum Detected Concentration	Maximum Detection Limit	Units	Detection Frequency	Exposure Point Concentration (1)	Units	Freshwater Ecological Screening Value (2)	Marine Ecological Screening Value (2)	Lowest Ecological Screening Value (3)	COPC Flag	Rationale for Contaminant Deletion or Selection	Hazard Quotient EPC / ESV
4-Chlorophenyl-phenylether	NA	50	µg/l	0/69	50	µg/l	0	0	0	NO*	NSL,ND	0
4-Methylphenol	NA	50	µg/l	0/83	50	µg/l	0	0	0	NO*	NSL,ND	0
4-Nitroaniline	NA	120	µg/l	0/65	120	µg/l	0	0	0	NO*	NSL,ND	0
4-Nitrophenol	NA	120	µg/l	0/65	120	µg/l	0	0	0	NO*	NSL,ND	0
Acenaphthene	NA	50	µg/l	0/83	50	µg/l	0	0	0	NO*	NSL,ND	0
Acenaphthylene	NA	50	µg/l	0/83	50	µg/l	0	0	0	NO*	NSL,ND	0
Aldrin	NA	0.05	µg/l	0/69	0.05	µg/l	3	1.3	1.3	NO	BSL	0.04
Anthracene	NA	50	µg/l	0/69	50	µg/l	0	0	0	NO*	NSL,ND	0
Aroclor-1016	NA	1	µg/l	0/65	1	µg/l	0	0	0	NO*	NSL,ND	0
Aroclor-1221	NA	2	µg/l	0/65	2	µg/l	0	0	0	NO*	NSL,ND	0
Aroclor-1232	NA	1	µg/l	0/65	1	µg/l	0	0	0	NO*	NSL,ND	0
Aroclor-1242	NA	1	µg/l	0/69	1	µg/l	0	0	0	NO*	NSL,ND	0
Aroclor-1248	NA	1	µg/l	0/69	1	µg/l	0	0	0	NO*	NSL,ND	0
Aroclor-1254	NA	1	µg/l	0/69	1	µg/l	0	0	0	NO*	NSL,ND	0
Aroclor-1260	NA	1	µg/l	0/69	1	µg/l	0	0	0	NO*	NSL,ND	0
Benzene	NA	10	µg/l	0/96	10	µg/l	1125	1350	1125	NO	BSL	0.01
Benz[a]anthracene	NA	50	µg/l	0/69	50	µg/l	0	0	0	NO*	NSL,ND	0
Benzo(a)pyrene	NA	10	µg/l	0/55	10	µg/l	0	0	0	NO*	NSL,ND	0
Benzo(b)fluoranthene	NA	50	µg/l	0/69	50	µg/l	0	0	0	NO*	NSL,ND	0
Benzo(g,h,i)perylene	NA	10	µg/l	0/55	10	µg/l	0	0	0	NO*	NSL,ND	0
Benzo(k)fluoranthene	NA	50	µg/l	0/69	50	µg/l	0	0	0	NO*	NSL,ND	0
Bromodichloromethane	NA	10	µg/l	0/92	10	µg/l	0	0	0	NO*	NSL,ND	0
Bromomethane	NA	10	µg/l	0/92	10	µg/l	0	0	0	NO*	NSL,ND	0
Butylbenzylphthalate	NA	50	µg/l	0/65	50	µg/l	0	0	0	NO*	NSL,ND	0
Carbazole	NA	50	µg/l	0/69	50	µg/l	0	0	0	NO*	NSL,ND	0
Carbon Tetrachloride	NA	10	µg/l	0/92	10	µg/l	1365	7500	1365	NO	BSL	0.01
Chlorobenzene	NA	10	µg/l	0/96	10	µg/l	0	0	0	NO*	NSL,ND	0
Chloroethane	NA	10	µg/l	0/92	10	µg/l	0	0	0	NO*	NSL,ND	0
Chloromethane	NA	10	µg/l	0/92	10	µg/l	27,500	13,500	13500	NO	BSL	0.001
Chrysene	NA	50	µg/l	0/69	50	µg/l	0	0	0	NO*	NSL,ND	0
Cobalt	NA	4	µg/l	0/132	4	µg/l	0	0	0	NO*	NSL,ND	0
Di-n-octylphthalate	NA	50	µg/l	0/69	50	µg/l	0	0	0	NO*	NSL,ND	0
Dibenz[a,h]anthracene	NA	10	µg/l	0/55	10	µg/l	0	0	0	NO*	NSL,ND	0

Table 3.3. Calculation of hazard quotients and selection of preliminary contaminants of potential concern (estuary-wide surface water data; from CDM 1999).

Chemical	Maximum Detected Concentration	Maximum Detection Limit	Units	Detection Frequency	Exposure Point Concentration (1)	Units	Freshwater Ecological Screening Value (2)	Marine Ecological Screening Value (2)	Lowest Ecological Screening Value (3)	COPC Flag	Rationale for Contaminant Deletion or Selection	Hazard Quotient EPC / ESV
Dibenzofuran	NA	50	µg/l	0/69	50	µg/l	0	0	0	NO*	NSL,ND	0
Dieldrin	NA	0.1	µg/l	0/69	0.1	µg/l	0.0019	0.0019	0.0019	YES	ASL	53
Endosulfan I	NA	0.05	µg/l	0/65	0.05	µg/l	0.056	0.0087	0.0087	YES	ASL	5.7
Endosulfan II	NA	0.1	µg/l	0/69	0.1	µg/l	0.056	0.0087	0.0087	YES	ASL	11
Endosulfan sulfate	NA	0.1	µg/l	0/68	0.1	µg/l	0	0	0	NO*	NSL,ND	0
Endrin	NA	0.1	µg/l	0/69	0.1	µg/l	0.0023	0.0023	0.0023	YES	ASL	43.48
Endrin aldehyde	NA	0.1	µg/l	0/69	0.1	µg/l	0	0	0	NO*	NSL,ND	0
Endrin ketone	NA	0.1	µg/l	0/69	0.1	µg/l	0	0	0	NO*	NSL,ND	0
Ethylbenzene	NA	10	µg/l	0/92	10	µg/l	1600	4380	1600	NO	BSL	0.01
Fluoranthene	NA	50	µg/l	0/69	50	µg/l	0	0	0	NO*	NSL,ND	0
Fluorene	NA	50	µg/l	0/69	50	µg/l	0	0	0	NO*	NSL,ND	0
Gasoline range organics	NA	25	µg/l	0/63	25	µg/l	0	0	0	NO*	NSL,ND	0
Heptachlor	NA	0.05	µg/l	0/69	0.05	µg/l	0.0038	0.0036	0.0036	YES	ASL	14
Heptachlor epoxide	NA	0.05	µg/l	0/69	0.05	µg/l	0.0038	0.0036	0.0036	YES	ASL	13.89
Hexachlorobenzene	NA	50	µg/l	0/69	50	µg/l	0	0	0	NO*	NSL,ND	0
Hexachlorocyclopentadiene	NA	50	µg/l	0/83	50	µg/l	0	0	0	NO*	NSL,ND	0
Hexachloroethane	NA	50	µg/l	0/83	50	µg/l	0	0	0	NO*	NSL,ND	0
Hexavalent chromium	NA	0.005	µg/l	0/7	0.005	µg/l	11	50	11	NO	BSL	0.0005
Indeno(1,2,3-cd)pyrene	NA	10	µg/l	0/55	10	µg/l	0	0	0	NO*	NSL,ND	0
Isophorone	NA	50	µg/l	0/79	50	µg/l	0	0	0	NO*	NSL,ND	0
Mercury	NA	0.2	µg/l	0/136	0.20	µg/l	0.012	0.025	0.012	YES	ASL	17
Methoxychlor	NA	0.5	µg/l	0/69	0.50	µg/l	0	0	0	NO*	NSL,ND	0
N-Nitroso-di-n-propylamine	NA	50	µg/l	0/79	50	µg/l	0	0	0	NO*	NSL,ND	0
N-Nitrosodiphenylamine	NA	50	µg/l	0/69	50	µg/l	0	0	0	NO*	NSL,ND	0
Naphthalene	NA	50	µg/l	0/83	50	µg/l	0	0	0	NO*	NSL,ND	0
Nitrobenzene	NA	50	µg/l	0/79	50	µg/l	0	0	0	NO*	NSL,ND	0
Pentachlorophenol	NA	120	µg/l	0/65	120	µg/l	15	7.9	7.9	YES	ASL	15
Phenanthrene	NA	50	µg/l	0/69	50	µg/l	0	0	0	NO*	NSL,ND	0
Phenol	NA	50	µg/l	0/83	50	µg/l	350	290	290	NO	BSL	0.17
Pyrene	NA	50	µg/l	0/69	50	µg/l	0	0	0	NO*	NSL,ND	0
Styrene	NA	10	µg/l	0/92	10	µg/l	0	0	0	NO*	NSL,ND	0
Toxaphene	NA	5	µg/l	0/65	5	µg/l	0.0002	0.0002	0.0002	YES	ASL	25000
Xylene (total)	NA	10	µg/l	0/96	10	µg/l	0	0	0	NO*	NSL,ND	0

Table 3.3. Calculation of hazard quotients and selection of preliminary contaminants of potential concern (estuary-wide surface water data; from CDM 1999).

Chemical	Maximum Detected Concentration	Maximum Detection Limit	Units	Detection Frequency	Exposure Point Concentration (1)	Units	Freshwater Ecological Screening Value (2)	Marine Ecological Screening Value (2)	Lowest Ecological Screening Value (3)	COPC Flag	Rationale for Contaminant Deletion or Selection	Hazard Quotient EPC / ESV
Alpha-benzene hexachloride (BHC)	NA	0.05	µg/l	0/69	0.05	µg/l	0	0	0	NO*	NSL,ND	0
Alpha-chlordane	NA	0.05	µg/l	0/69	0.05	µg/l	0.0043	0.004	0.004	YES	ASL	13
Beta-benzene hexachloride (BHC)	NA	0.05	µg/l	0/69	0.05	µg/l	0	0	0	NO*	NSL,ND	0
Bis(2-chloroethoxy)methane	NA	50	µg/l	0/79	50	µg/l	0	0	0	NO*	NSL,ND	0
Bis(2-chloroisopropyl)ether	NA	50	µg/l	0/79	50	µg/l	0	0	0	NO*	NSL,ND	0
Cis-1,3-dichloropropene	NA	10	µg/l	0/92	10	µg/l	303	39.5	39.5	NO	BSL	0.25
Delta-benzene hexachloride (BHC)	NA	0.25	µg/l	0/69	0.25	µg/l	0	0	0	NO*	NSL,ND	0
Gamma-benzene hexachloride (Lindane)	NA	0.05	µg/l	0/69	0.05	µg/l	0.21	0.16	0.16	NO	BSL	0.31
Trans-1,3-dichloropropene	NA	10	µg/l	0/92	10	µg/l	303	39.5	39.5	NO	BSL	0.25

(1) Maximum detected concentration. If chemical was not detected, maximum detection limit. Per verbal communication, USEPA, S. Bennett, 1999.
(2) Lesser of USEPA (1998b) and LDEQ (1998b).
(3) The lesser of the freshwater and marine values was selected as the ESV.
(4) Chemicals that do not have a screening toxicity value but are detected in at least one sample are retained as COPCs.

EPA = U.S. Environmental Protection Agency
ASL = Above Screening Levels
NSL,D = No Screening Level, Detected at Least Once
BSL = Below Screening Level
NSL,ND = No Screening Level, Not Detected
µg/l = micrograms per liter
% = percent
NA = Not Available/Not Applicable
COPC = Chemical of Potential Concern
NA = Not Applicable/Not Available
mg/l = milligrams per liter

EPC = Exposure Point Concentration
ESV = Ecological Screening Value
YES = COC, detected or with a detection limit exceeding screening toxicity value
YES* = COC, detected at least once but lacking a screening toxicity value
NO = Not a COC, did not exceed screening toxicity value
NO* = Not a COC, did not have a screening toxicity value and was not detected
PAH = Polycyclic aromatic hydrocarbon
umhos/cm = micromhos per centimeter
ppt = parts per trillion
ntu = nephelometric turbidity units

Table 3.4. Calculation of hazard quotients and selection of preliminary contaminants of potential concern (estuary-wide surface sediment data, 0-12 inches; from CDM 1999).

Chemical	Maximum Detected Concentration	Maximum Detection Limit	Units	Detection Frequency	Exposure Point Concentration (1)	Units	Freshwater Ecological Screening Value (2)	Marine Ecological Screening Value (2)	Lowest Ecological Screening Value (3)	COPC Flag	Rationale for Contaminant Deletion or Selection (4)	Hazard Quotient EPC / ESV
Acenaphthene	29524	29000	µg/kg	33/175	29524	µg/kg	16	6.71	6.71	YES	ASL	4400
Acenaphthylene	360	63462	µg/kg	3/138	360	µg/kg	44	5.87	5.87	YES	ASL	61
Acetone	12286	5000	µg/kg	79/175	12286	µg/kg	8.7	0	8.7	YES	ASL	1412
Aldrin	248	28	µg/kg	12/146	248	µg/kg	2	0	2	YES	ASL	124
Aluminum	271111	999	mg/kg	158/158	271111	mg/kg	0	0	0	YES*	NSL,D	0
Anthracene	40385	29000	µg/kg	52/175	40385	µg/kg	85.3	46.9	46.9	YES	ASL	861
Antimony	313	68	mg/kg	3/110	313	mg/kg	2	2	2	YES	ASL	157
Arsenic	24	7	mg/kg	163/176	24	mg/kg	8.2	7.24	7.24	YES	ASL	3.3
Aroclor 1016	130	280	µg/kg	1/98	130	µg/kg	7	0	7	YES	ASL	19
Aroclor 1221	260	560	µg/kg	1/98	260	µg/kg	120	0	120	YES	ASL	2.2
Aroclor 1232	130	280	µg/kg	1/98	130	µg/kg	600	0	600	NO	BSL	0.2
Aroclor 1242	210	970	µg/kg	3/127	210	µg/kg	170	0	170	YES	ASL	1.2
Aroclor 1248	270	970	µg/kg	4/127	270	µg/kg	30	0	30	YES	ASL	9
Aroclor 1254	2400	970	µg/kg	22/164	2400	µg/kg	60	0	60	YES	ASL	40
Aroclor 1260	980	970	µg/kg	13/146	980	µg/kg	5	0	5	YES	ASL	196
Bis(2-ethylhexyl)phthalate	57000	63462	µg/kg	36/175	57000	µg/kg	0	182	0	YES*	NSL,D	0
Benz[a]anthracene	160000	24000	µg/kg	76/175	160000	µg/kg	261	74.8	74.8	YES	ASL	2139
Dibenz[a,h]anthracene	64000	29000	µg/kg	42/175	64000	µg/kg	63.4	6.22	6.22	YES	ASL	10289
Benzo(a)pyrene	100000	26316	µg/kg	69/175	100000	µg/kg	430	88.8	88.8	YES	ASL	1126
Barium	2110	999	mg/kg	158/158	2110	mg/kg	0	0	0	YES*	NSL,D	0
Benzo(b)fluoranthene	130000	26316	µg/kg	70/175	130000	µg/kg	0	0	0	YES*	NSL,D	0
Benzene	58	5000	µg/kg	22/175	58	µg/kg	160	0	160	NO	BSL	0.4
Beryllium	4	2	mg/kg	130/176	4	mg/kg	0	0	0	YES*	NSL,D	0
Benzo(g,h,i)perylene	55769	29000	µg/kg	46/175	55769	µg/kg	0	0	0	YES*	NSL,D	0
Benzo(k)fluoranthene	6190	63462	µg/kg	28/157	6190	µg/kg	0	0	0	YES*	NSL,D	0
2-Butanone	100	5000	µg/kg	32/175	100	µg/kg	270	0	270	NO	BSL	0.4
Cadmium	11	22	mg/kg	26/158	11	mg/kg	1.2	0.676	0.676	YES	ASL	16
Calcium	321875	999	mg/kg	158/158	321875	mg/kg	0	0	0	NO	NA	0
Carbazole	7500	63462	µg/kg	2/153	7500	µg/kg	0	0	0	YES*	NSL,D	0
Chlordane - alpha	33	42	µg/kg	6/146	33	µg/kg	0.5	2.26	0.5	YES	ASL	66
Chlordane - gamma	160	41	µg/kg	8/146	160	µg/kg	0.5	2.26	0.5	YES	ASL	320
Chromium, total	239	999	mg/kg	38/38	239	mg/kg	81	52.3	52	YES	ASL	4.6

Table 3.4. Calculation of hazard quotients and selection of preliminary contaminants of potential concern (estuary-wide surface sediment data, 0-12 inches; from CDM 1999).

Chemical	Maximum Detected Concentration	Maximum Detection Limit	Units	Detection Frequency	Exposure Point Concentration (1)	Units	Freshwater Ecological Screening Value (2)	Marine Ecological Screening Value (2)	Lowest Ecological Screening Value (3)	COPC Flag	Rationale for Contaminant Deletion or Selection (4)	Hazard Quotient EPC / ESV
Chromium hexavalent	714	2	mg/kg	137/138	714	mg/kg	0	0	0	YES*	NSL,D	0
Chrysene	410000	24000	µg/kg	79/175	410000	µg/kg	384	108	108	YES	ASL	3796
4-Chloro-3-methylphenol	44	63462	µg/kg	2/128	44	µg/kg	0	0	0	YES*	NSL,D	0
Chlorobenzene	1500	5000	µg/kg	40/175	1500	µg/kg	410	0	410	YES	ASL	3.7
1,2,4-Trichlorobenzene	360	63462	µg/kg	5/138	360	µg/kg	9600	0	9600	NO	BSL	0.04
1,2-Dichlorobenzene	62	63462	µg/kg	1/116	62	µg/kg	330	0	330	NO	BSL	0.2
1,3-Dichlorobenzene	5900	63462	µg/kg	27/156	5900	µg/kg	1700	0	1700	YES	ASL	3.5
1,4-Dichlorobenzene	2200	63462	µg/kg	21/156	2200	µg/kg	340	0	340	YES	ASL	6.5
Hexachlorobenzene (HCB)	33000	63462	µg/kg	22/156	33000	µg/kg	20	0	20	YES	ASL	1650
Chlorinated benzenes, total	37500	63462	µg/kg	24/157	37500	µg/kg	0	0	0	YES*	NSL,D	0
Hexachlorobutadiene	3800	63462	µg/kg	13/155	3800	µg/kg	0	0	0	YES*	NSL,D	0
1,1,2-Trichloroethane	7	5000	µg/kg	2/157	7	µg/kg	0	0	0	YES*	NSL,D	0
1,2-Dichloroethane	65	5000	µg/kg	16/157	65	µg/kg	0	0	0	YES*	NSL,D	0
Hexachlorocyclohexane-alpha	7	50	µg/kg	1/127	7	µg/kg	6	0	6	YES	ASL	1.1
Hexachlorocyclohexane-beta	140	50	µg/kg	6/146	140	µg/kg	5	0	5	YES	ASL	28
Hexachlorocyclohexane-delta	7	50	µg/kg	9/146	7	µg/kg	0	0	0	YES*	NSL,D	0
Hexachlorocyclohexane-gamma (Lindane)	13	50	µg/kg	4/146	13	µg/kg	0.94	0.32	0.32	YES	ASL	41
Cobalt	802	45	mg/kg	140/158	802	mg/kg	0	0	0	YES*	NSL,D	0
Copper	639	11	mg/kg	172/176	639	mg/kg	34	18.7	19	YES	ASL	34
4-Chlorophenyl phenyl ether	280	63462	µg/kg	3/138	280	µg/kg	0	0	0	YES*	NSL,D	0
Carbon disulfide	177	5000	µg/kg	55/175	177	µg/kg	0.85	0	0.85	YES	ASL	208
Dibenzofuran	2708	63462	µg/kg	8/138	2708	µg/kg	420	0	420	YES	ASL	6.4
Dieldrin	47	82	µg/kg	8/127	47	µg/kg	0.02	0.715	0.02	YES	ASL	2350
Di-n-butyl phthalate	120	63462	µg/kg	7/175	120	µg/kg	0	0	0	YES*	NSL,D	0
Dimethyl phthalate	180	63462	µg/kg	1/138	180	µg/kg	0	0	0	YES*	NSL,D	0
Endosulfan-alpha	7	14	µg/kg	1/98	7	µg/kg	0	0	0	YES*	NSL,D	0
Endosulfan-beta	192	82	µg/kg	11/127	192	µg/kg	0	0	0	YES*	NSL,D	0
Endosulfan sulfate	13	28	µg/kg	1/98	13	µg/kg	0	0	0	YES*	NSL,D	0
Endrin	31	82	µg/kg	5/127	31	µg/kg	2.67	0.02	0.02	YES	ASL	1550
Endrin aldehyde	22	82	µg/kg	5/127	22	µg/kg	0	0	0	YES*	NSL,D	0
Endrin ketone	13	97	µg/kg	1/86	13	µg/kg	0	0	0	YES*	NSL,D	0
Ethylbenzene	4	5000	µg/kg	3/128	4	µg/kg	89	0	89	NO	BSL	0.05

Table 3.4. Calculation of hazard quotients and selection of preliminary contaminants of potential concern (estuary-wide surface sediment data, 0-12 inches; from CDM 1999).

Chemical	Maximum Detected Concentration	Maximum Detection Limit	Units	Detection Frequency	Exposure Point Concentration (1)	Units	Freshwater Ecological Screening Value (2)	Marine Ecological Screening Value (2)	Lowest Ecological Screening Value (3)	COPC Flag	Rationale for Contaminant Deletion or Selection (4)	Hazard Quotient EPC / ESV
Fluoranthene	104762	24000	µg/kg	81/175	104762	µg/kg	600	113	113	YES	ASL	927
Fluorene	37143	29000	µg/kg	41/175	37143	µg/kg	19	21.2	19	YES	ASL	1955
Heptachlor epoxide	7	50	µg/kg	1/127	7	µg/kg	0.6	0	0.6	YES	ASL	11
Heptachlor	61	28	µg/kg	9/127	61	µg/kg	68	0	68	NO	BSL	0.9
High molecular weight PAHs, total	1114000	656	µg/kg	90/106	1114000	µg/kg	1700	0	1700	YES	ASL	655
Indeno(1,2,3-c,d)pyrene	39000	29000	µg/kg	47/175	39000	µg/kg	0	0	0	YES*	NSL,D	0
Iron	72857	999	mg/kg	176/176	72857	mg/kg	20,000	0	20000	YES	ASL	3.6
Lead	544	9	mg/kg	175/176	544	mg/kg	47	30.2	30.2	YES	ASL	18
Low molecular weight PAHs, total	354000	164	µg/kg	78/95	354000	µg/kg	552	0	552	YES	ASL	641
Magnesium	63077	999	mg/kg	176/176	63077	mg/kg	0	0	0	NO	NA	0
Manganese	2200	999	mg/kg	176/176	2200	mg/kg	460	0	460	YES	ASL	4.8
Mercury	58	4	mg/kg	81/176	58	mg/kg	0.15	0.13	0.13	YES	ASL	446
2-Methylnaphthalene	64583	63462	µg/kg	46/175	64583	µg/kg	70	20.2	20.2	YES	ASL	3197
Methoxychlor	65	500	µg/kg	2/127	65	µg/kg	19	0	19	YES	ASL	3.4
Methylene chloride	110	5000	µg/kg	21/157	110	µg/kg	370	0	370	NO	BSL	0.3
2-Methylphenol	47	63462	µg/kg	1/138	47	µg/kg	12	0	12	YES	ASL	3.9
4-Methylphenol	83	63462	µg/kg	2/138	83	µg/kg	0	0	0	YES*	NSL,D	0
Naphthalene	19000	63462	µg/kg	27/175	19000	µg/kg	160	34.6	34.6	YES	ASL	549
Nickel	187	25	mg/kg	155/176	187	mg/kg	20.9	15.9	16	YES	ASL	12
N-nitrosodiphenylamine	1400	63462	µg/kg	7/135	1400	µg/kg	0	0	0	YES*	NSL,D	0
Polychlorinated biphenyls, total	2400	970	µg/kg	21/164	2400	µg/kg	22.7	21.5	21.5	YES	ASL	112
Fines, percent (silt+clay)	99	999	%	19/19	99	%	0	0	0	YES*	NSL,D	0
Sand, percent	67	999	%	19/19	67	%	0	0	0	YES*	NSL,D	0
Solids, percent	60	999	%	38/38	60	%	0	0	0	YES*	NSL,D	0
Petroleum hydrocarbons as gasolines	60000	25	mg/kg	35/78	60000	mg/kg	0	0	0	YES*	NSL,D	0
Petroleum hydrocarbons, total as diesel	6300	66	mg/kg	28/78	6300	mg/kg	0	0	0	YES*	NSL,D	0
Phenanthrene	250000	18000	µg/kg	78/175	250000	µg/kg	240	86.7	86.7	YES	ASL	2884
Phenol	844	63462	µg/kg	1/137	844	µg/kg	31	0	31	YES	ASL	27
Potassium	12524	2200	mg/kg	140/158	12524	mg/kg	0	0	0	YES*	NSL,D	0
4,4'-Dichlorodiphenyldichloroethane (DDD)	13	97	µg/kg	7/146	13	µg/kg	2	1.22	1.22	YES	ASL	11
4,4'-Dichlorodiphenyldichloroethene (DDE)	20	97	µg/kg	7/146	20	µg/kg	2.2	2.07	2.07	YES	ASL	10
4,4'-Dichlorodiphenyltrichloroethane (DDT)	13	28	µg/kg	1/98	13	µg/kg	1	1.19	1	YES	ASL	13

Table 3.4. Calculation of hazard quotients and selection of preliminary contaminants of potential concern (estuary-wide surface sediment data, 0-12 inches; from CDM 1999).

Chemical	Maximum Detected Concentration	Maximum Detection Limit	Units	Detection Frequency	Exposure Point Concentration (1)	Units	Freshwater Ecological Screening Value (2)	Marine Ecological Screening Value (2)	Lowest Ecological Screening Value (3)	COPC Flag	Rationale for Contaminant Deletion or Selection (4)	Hazard Quotient EPC / ESV
Pyrene	300000	24000	µg/kg	94/175	300000	µg/kg	665	153	153	YES	ASL	1961
Selenium	16	9	mg/kg	64/176	16	mg/kg	0	0	0	YES*	NSL,D	0
Silver	13	10	mg/kg	13/139	13	mg/kg	1	0.73	0.73	YES	ASL	18
Sodium	89524	999	mg/kg	158/158	89524	mg/kg	0	0	0	NO	NA	0
Thallium	17	13	mg/kg	12/128	17	mg/kg	0	0	0	YES*	NSL,D	0
Organic carbon, total	200	999	%	50/50	200	%	0	0	0	YES*	NSL,D	0
Toluene	32	5000	µg/kg	16/175	32	µg/kg	50	0	50	NO	BSL	0.6
Benzene hexachloride (BHC), total	153	50	µg/kg	8/146	153	µg/kg	3	0	3	YES	ASL	51
Polycyclic aromatic hydrocarbons, total	1468000	656	µg/kg	91/107	1468000	µg/kg	4022	1022	1022	YES	ASL	1436
Toxaphene	650	1400	µg/kg	1/98	650	µg/kg	0	0	0	YES*	NSL,D	0
Vanadium	129	2	mg/kg	157/158	129	mg/kg	0	0	0	YES*	NSL,D	0
Vinyl chloride	141	5000	µg/kg	1/157	141	µg/kg	0	0	0	YES*	NSL,D	0
Xylenes, total	245	5000	µg/kg	20/155	245	µg/kg	160	0	160	YES	ASL	1.5
Zinc	2830	999	mg/kg	176/176	2830	mg/kg	150	124	124	YES	ASL	23
Acrolein	NA	5000	µg/kg	0/20	5000	µg/kg	0	0	0	NO*	NSL,ND	0
Acrylonitrile	NA	5000	µg/kg	0/20	5000	µg/kg	0	0	0	NO*	NSL,ND	0
Bis(2-chloroethyl)ether	NA	63462	µg/kg	0/138	63462	µg/kg	0	0	0	NO*	NSL,ND	0
Bis(2-chloroisopropyl) ether	NA	63462	µg/kg	0/109	63462	µg/kg	0	0	0	NO*	NSL,ND	0
Bis(2-chloroethoxy)methane	NA	63462	µg/kg	0/109	63462	µg/kg	0	0	0	NO*	NSL,ND	0
Benzoic acid	NA	820	µg/kg	0/20	820	µg/kg	0	0	0	NO*	NSL,ND	0
Benzyl alcohol	NA	328	µg/kg	0/20	328	µg/kg	0	0	0	NO*	NSL,ND	0
4-Bromophenyl phenyl ether	NA	63462	µg/kg	0/138	63462	µg/kg	1200	0	1200	YES	ASL	53
Dibromochloromethane	NA	5000	µg/kg	0/139	5000	µg/kg	0	0	0	NO*	NSL,ND	0
Bromomethane	NA	5000	µg/kg	0/110	5000	µg/kg	0	0	0	NO*	NSL,ND	0
Bromoform	NA	5000	µg/kg	0/139	5000	µg/kg	0	0	0	NO*	NSL,ND	0
Butylbenzyl phthalate	NA	63462	µg/kg	0/109	63462	µg/kg	0	0	0	NO*	NSL,ND	0
Benzidine	NA	1640	µg/kg	0/20	1640	µg/kg	1.7	0	1.7	YES	ASL	965
Cis-1,2-dichlorethene	NA	100	µg/kg	0/8	100	µg/kg	0	0	0	NO*	NSL,ND	0
Cis-1,3-dichloropropene	NA	5000	µg/kg	0/110	5000	µg/kg	0	0	0	NO*	NSL,ND	0
Carbon tetrachloride	NA	5000	µg/kg	0/110	5000	µg/kg	47	0	47	YES	ASL	106
Chloroform	NA	5000	µg/kg	0/157	5000	µg/kg	22	0	22	YES	ASL	227
4-Chloroaniline	NA	63462	µg/kg	0/109	63462	µg/kg	0	0	0	NO*	NSL,ND	0

Table 3.4. Calculation of hazard quotients and selection of preliminary contaminants of potential concern (estuary-wide surface sediment data, 0-12 inches; from CDM 1999).

Chemical	Maximum Detected Concentration	Maximum Detection Limit	Units	Detection Frequency	Exposure Point Concentration (1)	Units	Freshwater Ecological Screening Value (2)	Marine Ecological Screening Value (2)	Lowest Ecological Screening Value (3)	COPC Flag	Rationale for Contaminant Deletion or Selection (4)	Hazard Quotient EPC / ESV
Bromodichloromethane	NA	5000	µg/kg	0/110	5000	µg/kg	0	0	0	NO*	NSL,ND	0
3,3'-Dichlorobenzidine	NA	63462	µg/kg	0/109	63462	µg/kg	0	0	0	NO*	NSL,ND	0
Hexachlorocyclopentadiene	NA	63462	µg/kg	0/125	63462	µg/kg	0	0	0	NO*	NSL,ND	0
1,1,2,2-Tetrachloroethane	NA	5000	µg/kg	0/157	5000	µg/kg	1400	0	1400	YES	ASL	3.6
Chloroethane	NA	5000	µg/kg	0/128	5000	µg/kg	0	0	0	NO*	NSL,ND	0
1,1,1-Trichloroethane	NA	5000	µg/kg	0/139	5000	µg/kg	30	0	30	YES	ASL	167
1,1'-Dichloroethane	NA	5000	µg/kg	0/157	5000	µg/kg	0	0	0	NO*	NSL,ND	0
Hexachloroethane	NA	63462	µg/kg	0/138	63462	µg/kg	1000	0	1000	YES	ASL	63
1,1'-Dichloroethene	NA	5000	µg/kg	0/157	5000	µg/kg	0	0	0	NO*	NSL,ND	0
1,2-Dichloroethene	NA	5000	µg/kg	0/149	5000	µg/kg	0	0	0	NO*	NSL,ND	0
Trichloroethene	NA	5000	µg/kg	0/157	5000	µg/kg	0	0	0	NO*	NSL,ND	0
Chloromethane	NA	5000	µg/kg	0/110	5000	µg/kg	0	0	0	NO*	NSL,ND	0
2-Chloronaphthalene	NA	63462	µg/kg	0/109	63462	µg/kg	0	0	0	NO*	NSL,ND	0
2,4,5-Trichlorophenol	NA	153846	µg/kg	0/109	153846	µg/kg	0	0	0	NO*	NSL,ND	0
2,4,6-Trichlorophenol	NA	63462	µg/kg	0/109	63462	µg/kg	0	0	0	NO*	NSL,ND	0
2,4-Dichlorophenol	NA	63462	µg/kg	0/109	63462	µg/kg	0	0	0	NO*	NSL,ND	0
Pentachlorophenol	NA	153846	µg/kg	0/109	153846	µg/kg	0	0	0	NO*	NSL,ND	0
2-Chlorophenol	NA	63462	µg/kg	0/109	63462	µg/kg	0	0	0	NO*	NSL,ND	0
1,2-Dichloropropane	NA	5000	µg/kg	0/110	5000	µg/kg	0	0	0	NO*	NSL,ND	0
Diethyl phthalate	NA	63462	µg/kg	0/109	63462	µg/kg	0	0	0	NO*	NSL,ND	0
Diazinon	NA	18	µg/kg	0/20	18	µg/kg	1.9	0	1.9	YES	ASL	9.5
4,6-dinitro-2-methylphenol	NA	153846	µg/kg	0/109	153846	µg/kg	0	0	0	NO*	NSL,ND	0
2,4-dinitrophenol	NA	153846	µg/kg	0/109	153846	µg/kg	0	0	0	NO*	NSL,ND	0
2-Hexanone	NA	5000	µg/kg	0/110	5000	µg/kg	22	0	22	YES	ASL	227
Isophorone	NA	63462	µg/kg	0/109	63462	µg/kg	0	0	0	NO*	NSL,ND	0
4-Methyl-2-pentanone	NA	5000	µg/kg	0/110	5000	µg/kg	33	0	33	YES	ASL	152
2,4-Dimethylphenol	NA	63462	µg/kg	0/109	63462	µg/kg	0	0	0	NO*	NSL,ND	0
m,p-Xylene	NA	250	µg/kg	0/20	250	µg/kg	0	0	0	NO*	NSL,ND	0
2-Nitroaniline	NA	153846	µg/kg	0/109	153846	µg/kg	0	0	0	NO*	NSL,ND	0
3-Nitroaniline	NA	153846	µg/kg	0/109	153846	µg/kg	0	0	0	NO*	NSL,ND	0
4-Nitroaniline	NA	153846	µg/kg	0/109	153846	µg/kg	0	0	0	NO*	NSL,ND	0
Nitrobenzene	NA	63462	µg/kg	0/109	63462	µg/kg	0	0	0	NO*	NSL,ND	0

Table 3.4. Calculation of hazard quotients and selection of preliminary contaminants of potential concern (estuary-wide surface sediment data, 0-12 inches; from CDM 1999).

Chemical	Maximum Detected Concentration	Maximum Detection Limit	Units	Detection Frequency	Exposure Point Concentration (1)	Units	Freshwater Ecological Screening Value (2)	Marine Ecological Screening Value (2)	Lowest Ecological Screening Value (3)	COPC Flag	Rationale for Contaminant Deletion or Selection (4)	Hazard Quotient EPC / ESV
N-nitrosodi-N-propylamine	NA	63462	µg/kg	0/109	63462	µg/kg	0	0	0	NO*	NSL,ND	0
Di-N-octyl phthalate	NA	63462	µg/kg	0/138	63462	µg/kg	0	0	0	NO*	NSL,ND	0
2-Nitrophenol	NA	63462	µg/kg	0/109	63462	µg/kg	0	0	0	NO*	NSL,ND	0
4-Nitrophenol	NA	153846	µg/kg	0/109	153846	µg/kg	0	0	0	NO*	NSL,ND	0
2,4-Dinitrotoluene	NA	63462	µg/kg	0/109	63462	µg/kg	0	0	0	NO*	NSL,ND	0
2,6-Dinitrotoluene	NA	63462	µg/kg	0/109	63462	µg/kg	0	0	0	NO*	NSL,ND	0
Xylene, ortho-	NA	250	µg/kg	0/20	250	µg/kg	0	0	0	NO*	NSL,ND	0
Styrene	NA	5000	µg/kg	0/110	5000	µg/kg	0	0	0	NO*	NSL,ND	0
Trans-1,2-dichloroethene	NA	100	µg/kg	0/8	100	µg/kg	0	0	0	NO*	NSL,ND	0
Trans-1,3-dichloropropene	NA	5000	µg/kg	0/110	5000	µg/kg	0	0	0	NO*	NSL,ND	0

(1) Maximum detected concentration. If chemical was not detected, maximum detection limit. Per verbal communication, USEPA, S. Bennett, 1999.
(2) Hierarchy for ESV is NOAA 1997, CCME 1996, and EC 1998.
(3) The lesser of the freshwater and marine values was selected as the ESV.
(4) Chemicals that do not have a screening toxicity value but are detected in at least one sample are retained as COPCs.

ASL = Above Screening Levels
NSL,D = No Screening Level, Detected at Least Once
BSL = Below Screening Level
NSL,ND = No Screening Level, Not Detected
µg/kg = micrograms per kilogram
% = percent
NA = Not Available/Not Applicable
COPC = Chemical of Potential Concern

EPC = Exposure Point Concentration
ESV = Ecological Screening Value
mg/kg = milligrams per kilogram
YES = COC, detected or with a detection limit exceeding screening toxicity value
YES* = COC, detected at least once but lacking a screening toxicity value
NO = Not a COC, did not exceed screening toxicity value
NO* = Not a COC, did not have a screening toxicity value and was not detected
PAH = Polycyclic aromatic hydrocarbon

Table 3.5. Calculation of hazard quotients and selection of preliminary contaminants of potential concern (estuary-wide fish data; from CDM 1999).

Chemical	Maximum Detected Concentration	Maximum Detection Limit	Units	Detection Frequency	Exposure Point Concentration (1)	Units	Ecological Screening Value (2)	COPC Flag	Rationale for Contaminant Deletion or Selection	Hazard Quotient EPC / ESV
Aroclor 1254	1080	10	µg/kg	140/206	1080	µg/kg	355	YES	ASL	3.0
1,2,3-Trichlorobenzene	13.8	40	µg/kg	7/206	13.8	µg/kg	0	YES*	NSL,D	0
1,2,4-Trichlorobenzene	447	4.3	µg/kg	42/206	447	µg/kg	0	YES*	NSL,D	0
1,2-Dichlorobenzene	246	400	µg/kg	11/206	246	µg/kg	0	YES*	NSL,D	0
1,3,5-Trichlorobenzene	840	40	µg/kg	11/206	840	µg/kg	0	YES*	NSL,D	0
1,3-Dichlorobenzene	36.7	400	µg/kg	1/206	36.7	µg/kg	0	YES*	NSL,D	0
Pentachlorobenzene	2240	3	µg/kg	125/206	2240	µg/kg	0	YES*	NSL,D	0
Hexachlorobenzene (HCB)	1230	3	µg/kg	132/206	1230	µg/kg	0	YES*	NSL,D	0
Chlorinated benzenes, total	4153	26	µg/kg	206/248	4153	µg/kg	0	YES*	NSL,D	0
Hexachlorobutadiene	11600	21	µg/kg	165/206	11600	µg/kg	0	YES*	NSL,D	0
1,2,3,4-Tetrachlorobenzene	532	42	µg/kg	74/206	532	µg/kg	0	YES*	NSL,D	0
1,2,4,5-Tetrachlorobenzene	309	40	µg/kg	26/206	309	µg/kg	0	YES*	NSL,D	0
Hexachloroethane	176	5	µg/kg	27/206	176	µg/kg	0	YES*	NSL,D	0
Pentachloroethane	85.1	5	µg/kg	24/206	85.1	µg/kg	0	YES*	NSL,D	0
Lipids, percent	15.1	NA	%	206/206	15.1	%	0	YES*	NSL,D	0
Mercury	0.781	NA	mg/kg	30/30	0.781	mg/kg	0.013	YES	ASL	60.1
Polychlorinated biphenyls, total	1080	10	µg/kg	140/206	1080	µg/kg	0	YES*	NSL,D	0
Aroclor 1016	NA	100	µg/kg	0/206	100	µg/kg	10000	NO	BSL	0.01
Aroclor 1221	NA	100	µg/kg	0/206	100	µg/kg	0	NO*	NSL,ND	0
Aroclor 1232	NA	100	µg/kg	0/206	100	µg/kg	0	NO*	NSL,ND	0
Aroclor 1242	NA	100	µg/kg	0/206	100	µg/kg	504	NO	BSL	0.2
Aroclor 1248	NA	100	µg/kg	0/206	100	µg/kg	109	NO	BSL	0.9
Aroclor 1260	NA	16	µg/kg	0/206	16	µg/kg	0	NO*	NSL,ND	0

(1) Maximum detected concentration. If chemical was not detected, maximum detection limit. Per verbal communication, USEPA, S. Bennett, 1999.

(2) Toxicological Benchmarks for Wildlife: 1996 Revision. Sample, Opresko, and Suter. 1996. Most conservative value for all piscivorus species.

(3) Chemicals that do not have a screening toxicity value but are detected in at least one sample are retained as COPCs.

ASL = Above Screening Levels

NSL,D = No Screening Level, Detected at Least Once

EPC = Exposure Point Concentration

ESV = Ecological Screening Value

Table 3.5. Calculation of hazard quotients and selection of preliminary contaminants of potential concern (estuary-wide fish data; from CDM 1999).

Chemical	Maximum Detected Concentration	Maximum Detection Limit	Units	Detection Frequency	Exposure Point Concentration (1)	Units	Ecological Screening Value (2)	COPC Flag	Rationale for Contaminant Deletion or Selection	Hazard Quotient EPC / ESV

BSL = Below Screening Level
NSL,ND = No Screening Level, Not Detected
µg/kg = micrograms per kilogram
% = percent
NA = Not Available/Not Applicable
COPC = Chemical of Potential Concern

mg/kg = milligrams per kilogram
YES = COC, detected or with a detection limit exceeding screening toxicity value
YES* = COC, detected at least once but lacking a screening toxicity value
NO = Not a COC, did not exceed screening toxicity value
NO* = Not a COC, did not have a screening toxicity value and was not detected

Table 3.6. Calculation of hazard quotients and selection of preliminary contaminants of potential concern (estuary-wide crustacean data; from CDM 1999).

Chemical	Maximum Detected Concentration	Maximum Detection Limit	Units	Detection Frequency	Exposure Point Concentration (1)	Units	Ecological Screening Value (2)	COPC Flag	Rationale for Contaminant Deletion or Selection (3)	Hazard Quotient EPC / ESV
Aroclor 1254	574	17	µg/kg	108/148	574	µg/kg	355	YES	ASL	1.6
Aroclor 1260	10.8	76.6	µg/kg	1/148	10.8	µg/kg	0	YES*	NSL,D	0
1,2,3-Trichlorobenzene	100	4	µg/kg	28/148	100	µg/kg	0	YES*	NSL,D	0
1,2,4-Trichlorobenzene	272	21.8	µg/kg	50/148	272	µg/kg	0	YES*	NSL,D	0
1,2-Dichlorobenzene	140	37	µg/kg	13/148	140	µg/kg	0	YES*	NSL,D	0
1,3,5-Trichlorobenzene	41.2	3.33	µg/kg	14/148	41.2	µg/kg	0	YES*	NSL,D	0
1,3-Dichlorobenzene	54.8	44	µg/kg	1/148	54.8	µg/kg	0	YES*	NSL,D	0
Pentachlorobenzene	986	3.08	µg/kg	105/148	986	µg/kg	0	YES*	NSL,D	0
Hexachlorobenzene (HCB)	1470	3.08	µg/kg	120/148	1470	µg/kg	0	YES*	NSL,D	0
Chlorinated benzenes, total	2193	31.1	µg/kg	148/169	2193	µg/kg	0	YES*	NSL,D	0
Hexachlorobutadiene	2500	4	µg/kg	90/148	2500	µg/kg	0	YES*	NSL,D	0
1,2,3,4-Tetrachlorobenzene	311	4	µg/kg	79/148	311	µg/kg	0	YES*	NSL,D	0
1,2,4,5-Tetrachlorobenzene	36.4	7.54	µg/kg	19/148	36.4	µg/kg	0	YES*	NSL,D	0
Hexachloroethane	28	8	µg/kg	3/148	28	µg/kg	0	YES*	NSL,D	0
Pentachloroethane	28.6	5	µg/kg	16/148	28.6	µg/kg	0	YES*	NSL,D	0
Lipids, percent	4.2	NA	%	149/149	4.2	%	0	NO	NA	0
Mercury	0.412	NA	mg/kg	15/15	0.412	mg/kg	0.013	YES	ASL	31.7
Polychlorinated biphenyls, total	574	100	µg/kg	106/148	574	µg/kg	0	YES*	NSL,D	0
Aroclor 1016	NA	100	µg/kg	0/148	100	µg/kg	10000	NO	BSL	0.01
Aroclor 1221	NA	100	µg/kg	0/148	100	µg/kg	0	NO*	NSL,ND	0
Aroclor 1232	NA	100	µg/kg	0/148	100	µg/kg	0	NO*	NSL,ND	0
Aroclor 1242	NA	100	µg/kg	0/148	100	µg/kg	504	NO	BSL	0.2
Aroclor 1248	NA	100	µg/kg	0/148	100	µg/kg	109	NO	BSL	0.9

(1) Maximum detected concentration. If chemical was not detected, maximum detection limit. Per verbal communication, USEPA, S. Bennett, 1999.

(2) Toxicological Benchmarks for Wildlife: 1996 Revision. Sample, Opresko, and Suter. 1996. Most conservative value for all piscivorus species.

(3) Chemicals that do not have a screening toxicity value but are detected in at least one sample are retained as COPCs.

ASL = Above Screening Levels

NSL,D = No Screening Level, Detected at Least Once

EPC = Exposure Point Concentration

ESV = Ecological Screening Value

Table 3.6. Calculation of hazard quotients and selection of preliminary contaminants of potential concern (estuary-wide crustacean data; from CDM 1999).

Chemical	Maximum Detected Concentration	Maximum Detection Limit	Units	Detection Frequency	Exposure Point Concentration (1)	Units	Ecological Screening Value (2)	COPC Flag	Rationale for Contaminant Deletion or Selection (3)	Hazard Quotient EPC / ESV

BSL = Below Screening Level
NSL,ND = No Screening Level, Not Detected
µg/kg = micrograms per kilogram
% = percent
NA = Not Available/Not Applicable
COPC = Chemical of Potential Concern

mg/kg = milligrams per kilogram
YES = COC, detected or with a detection limit exceeding screening toxicity value
YES* = COC, detected at least once but lacking a screening toxicity value
NO = Not a COC, did not exceed screening toxicity value
NO* = Not a COC, did not have a screening toxicity value and was not detected

Table 5.1. Classification of contaminants of potential concern in the Calcasieu Estuary, based on their environmental fate and effects (MacDonald *et al.* 2000a).

Classification	Chemical Class/Substance
Bioaccumulative substances	**Metals** Mercury **PAHs** High molecular weight PAHs *Acenaphthene, Acenaphthylene, Anthracene, Fluorene, 2-Methylnaphthalene, Naphthalene, Phenanthrene* Low molecular weight PAHs *Benz[a]anthracene, Benzo(a)pyrene, Chrysene, Dibenz[a,h]anthracene, Fluoranthene, Pyrene* Total LMW-PAHs, Total HMW-PAHs, Total PAHs, Other PAHs **PCBs** Aroclors, PCB congeners, Total PCBs **PCDD** **PCDF** **Chlorinated benzenes** Hexachlorobenzene, Hexachlorobutadiene, Degradation products **Organochlorine pesticides** Aldrin, Dieldrin
Toxic substances that partition into sediments	**Metals** Chromium, Copper, Lead, Mercury, Nickel, Zinc **PAHs** High molecular weight PAHs *Acenaphthene, Acenaphthylene, Anthracene, Fluorene, 2-Methylnaphthalene, Naphthalene, Phenanthrene* Low molecular weight PAHs *Benz[a]anthracene, Benzo(a)pyrene, Chrysene, Dibenz[a,h]anthracene, Fluoranthene, Pyrene* Total LMW-PAHs, Total HMW-PAHs, Total PAHs, Other PAHs **PCBs** Aroclors, PCB congeners, Total PCBs **Chlorinated Benzenes** Hexachlorobenzene, Hexachlorobutadienes, Degradation products **Bis(2-ethylhexyl)phthalate**

Table 5.1. Classification of contaminants of potential concern in the Calcasieu Estuary, based on their environmental fate and effects (MacDonald *et al.* 2000a).

Classification	Chemical Class/Substance
Toxic substances that partition into sediments (cont.)	**Organochlorine pesticides** Aldrin, Dieldrin **Carbon disulfide** **Acetone** **Unionized ammonia (NH_3)** **Hydrogen sulfide (H_2S)**
Toxic substances that partition into surface water	**Metals** Copper, Mercury **VOCs** 1,2-Dichloroethane, Trichloroethane
Toxic substances that partition into the surface microlayer	**Metals** **VOCs** [e.g., 1,2-Dichloroethane, Trichloroethane] **SVOCs** [e.g., PAHs, Hexachlorobenzene, Hexachlorobutadienes, Bis(2-ethylhexyl)phthalate]

PCBs = Polychlorinated biphenyls; PAHs = Polycyclic aromatic hydrocarbons; PCDD = Polychlorinated dibenzo-p-dioxins; PCDF = Polychlorinated dibenzofurans; VOCs = Volatile organic chemicals; SVOCs = Semi-volatile organic chemicals.

Table 5.2. Key exposure routes for various classes of contaminants of potential concern in the Calcasieu Estuary.

Classification	Substances	Exposure Route - Aquatic		Exposure Route - Wildlife		
		Contact	Ingestion	Inhalation	Contact	Ingestion
Bioaccumulative substances	Mercury, PAHs, PCBs, PCDDs, PCDFs, Hexachlorobenzene, Hexachlorobutadiene, Aldrin, Dieldrin	✓	✓			✓
Toxic substances that partition into sediments	Copper, Chromium, Lead, Mercury, Nickel, Zinc, PAHs, PCBs, Hexachlorobenzene, Hexachlorobutadiene, Bis(2-ethylhexyl)phthalate, Aldrin and Dieldrin, Carbon disulfide, Acetone, Unionized ammonia, Hydrogen sulfide	✓	✓			✓
Toxic substances that partition into surface water	Copper, Mercury, 1,2-Dichloroethane, Trichloroethane	✓				✓
Toxic substances that partition into the surface microlayer	Metals, VOCs, SVOCs	✓		✓		

PCBs = Polychlorinated biphenyls; PAHs = Polycyclic aromatic hydrocarbons; PCDD = Polychlorinated dibenzo-p-dioxins; PCDF = Polychlorinated dibenzofurans; VOCs = Volatile organic chemicals; SVOCs = Semi-volatile organic chemicals.

Table 5.3. Receptor groups exposed to various classes of contaminants of potential concern in the Calcasieu Estuary.

Classification	Substances	Ecological Receptors		
		Aquatic Organisms	Birds	Mammals
Bioaccumulative substances	Mercury, PAHs, PCBs, PCDDs, PCDFs, Hexachlorobenzene, Hexachlorobutadiene, Aldrin, Dieldrin	Benthic invertebrates, Carnivorous fish, Amphibians, Reptiles	Insectivorus birds; Sediment-probing birds, Carnivorous wading birds, Piscivorus birds	Piscivorus mammals, Omnivorous mammals
Toxic substances that partition into sediments	Copper, Chromium, Lead, Mercury, Nickel, Zinc, PAHs, PCBs, Hexachlorobenzene, Hexachlorobutadiene, Bis(2-ethylhexyl)phthalate, Aldrin and Dieldrin, Carbon disulfide, Acetone, Unionized ammonia, Hydrogen sulfide	Decomposers, Aquatic plants, Benthic invertebrates, Benthic fish, Reptiles, Amphibians	Sediment-probing birds	
Toxic substances that partition into surface water	Copper, Mercury, 1,2-Dichloroethane, Trichloroethane	Aquatic plants, Aquatic invertebrates, Fish, Amphibians		
Toxic substances that partition into the surface microlayer	Metals, VOCs, SVOCs	Aquatic invertebrates, Pelagic fish	Birds	Piscivorus mammals

PCBs = Polychlorinated biphenyls; PAHs = Polycyclic aromatic hydrocarbons; PCDD = Polychlorinated dibenzo-p-dioxins; PCDF = Polychlorinated dibenzofurans; VOCs = Volatile organic chemicals; SVOCs = Semi-volatile organic chemicals.

Table 6.1. Listing of threatened and endangered species in the Calcasieu Estuary.

Common Name	Scientific Name	Federal Listing[2]	State Listing[1]
Reptiles			
American alligator[3]	*Alligator mississippiensis*	Threatened (S/A)	
Birds			
Bald eagle	*Haliaeetus leucocephalus*	Threatened	Endangered
Brown pelican[4]	*Pelecanus occidentalis*	Endangered	Endangered

[1]State listing (LDWF 2001).

[2]Federal listing (Watson 2001).

[3]Although the American alligator was designated as fully recovered as of 1987, it is included on the list because it is similar in appearance to several threatened or endangered crocodile and caiman species.

[4]Confirmation that this species exists in the study area by observation by John Meyer (USEPA) and Paul Conzelmann (US Parks Service).

S/A = similarity in appearance to a threatened taxon.

Table 7.1. Documented effects of contaminants of potential concern in the Calcasieu Estuary on aquatic organisms.

	Aquatic Plants			Zooplankton			Benthic Invertebrates			Fish		
Substance	**S**	**G**	**R**	**S**	**G**	**R**	**S**	**G**	**R**	**S**	**G**	**R**
Copper	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓
Chromium	✓	✓	✓	✓	✓	✓	✓			✓	✓	
Lead				✓	✓	✓	✓					
Mercury		✓		✓			✓		✓	✓	✓	✓
Nickel	✓	✓	✓	✓	✓	✓				✓		✓
Zinc	✓	✓	✓	✓	✓	✓	✓			✓		✓
PAHs				✓	✓	✓	✓	✓	✓	✓	✓	✓
PCBs				✓	✓	✓	✓	✓	✓	✓	✓	✓
PCDDs/PCDFs							✓	✓		✓	✓	✓
Chlorinated benzenes (HCB, HCBD)		✓		✓		✓			✓	✓		
Phthalates (BEHP)				✓						✓		
Chlorinated ethanes (TCA, DCE)							✓		✓	✓		
Carbon disulfide				✓						✓		
Acetone				✓						✓		
Organochlorine pesticides (Aldrin, Dieldrin)				✓			✓		✓	✓		

Effects: S = survival; G = growth; R = reproduction; ✓ = effects documented
PAHs = Polycyclic aromatic hydrocarbons; PCBs = Polychlorinated biphenyls; PCDD = Polychlorinated dibenzo-p-dioxins; PCDF = Polychlorinated dibenzofurans;
HCB = Hexachlorobenzene; HCBD = Hexaclorobutadiene; TCA = Trichloroethane; DCE = Dichloroethane; BEHP = Bis(2-ethylhexyl)phthalate.

Table 7.2. Documented effects of contaminants of potential concern in the Calcasieu Estuary on aquatic-dependent wildlife.

Substance	Birds					Mammals				
	S	G	R	C	I	S	G	R	C	I
Copper	✓	✓				✓	✓			
Chromium	✓	✓	✓			✓	✓	✓		
Lead	✓	✓	✓			✓	✓	✓		
Mercury	✓	✓	✓		✓	✓	✓	✓		✓
Nickel	✓	✓		P		✓	✓		P	
Zinc	✓	✓				✓	✓			
PAHs	✓		✓	✓		✓		✓	✓	
PCBs	✓	✓	✓			✓	✓	✓		
PCDDs/PCDFs	✓	✓	✓	P	P	✓	✓	✓	P	P
Chlorinated benzenes (HCB, HCBD)		✓	✓	✓	✓		✓	✓	✓	✓
Phthalates (BEHP)	✓	✓	✓	P		✓	✓	✓	P	
Chlorinated ethanes (TCA, DCE)	✓			✓		✓			✓	
Carbon disulfide										
Acetone	✓		✓			✓		✓		
Organochlorine pesticides (Aldrin, Dieldrin)	✓			P	✓	✓			P	✓

Effects: S = survival; G = growth; R = reproduction; C = tumor induction; I = immune system; ✓ = effects documented ; P = effects indicated but not clearly demonstrated.
PAHs = Polycyclic aromatic hydrocarbons; PCBs = Polychlorinated biphenyls; PCDD = Polychlorinated dibenzo-p-dioxins; PCDF = Polychlorinated dibenzofurans;
HCB = Hexachlorobenzene; HCBD = Hexaclorobutadiene; TCA = Trichloroethane; DCE = Dichloroethane; BEHP = Bis(2-ethylhexyl)phthalate.

Table 8.1. Candidate assessment and measurement endpoints for bioaccumulative substances (MacDonald *et al.* 2000a).

Receptor	Assessment Endpoint	Focal Species	Candidate Measurement Endpoints
Benthic invertebrates	Survival and Growth	Blue crabs, bivalves (*Rangia sp.*), other crabs	Contaminant levels in tissues of crabs, bivalves, shrimp. Abundance and distribution of focal species. Contaminant levels in tissues of prey species.
Carnivorous fish	Survival, Growth, and Reproduction	Redfish (benthic feeder), black drum (mollusc and sediment ingestion), seatrout (pelagic feeder), flounder (pelagic feeder), gar (pelagic feeder)	Fish community status (creel or targeted surveys). Contaminant levels in tissues of prey species. Contaminant levels in tissues of carnivorous fish. Fecundity (i.e., in killifish). Fish health (% incidence of DELT abnormalities). Contaminant accumulation rates (feeding trials).
Reptiles	Survival, Growth, and Reproduction	Alligators, snapping turtles, snakes	Penis size in turtles.
Amphibians	Survival, Growth, and Reproduction	Bull frogs, leopard frogs, pig frogs	None suggested.
Insectivorous birds	Survival and Reproduction	Swallows, purple martins	Tissue residues and biomarkers in eggs and other tissues. Reproductive success. Developmental abnormalities.
Sediment-probing birds	Survival and Reproduction	Sandpipers, willet, spoonbills, stilts, ibis, ducks	Contaminant levels in tissues of prey species. Tissue residues and biomarkers in eggs and other tissues. Behavioral abnormalities. Accumulation rates and effects in feeding trials.

Table 8.1. Candidate assessment and measurement endpoints for bioaccumulative substances (MacDonald *et al.* 2000a).

Receptor	**Assessment Endpoint**	**Focal Species**	**Candidate Measurement Endpoints**
Carnivorous wading birds	Survival and Reproduction	Great blue heron, great egret	Contaminant levels in tissues of prey species. Tissue residues and biomarkers in eggs and other tissues. Behavioral abnormalities. Reproductive success. Developmental abnormalities.
Piscivorus birds	Survival and Reproduction	Osprey (feed on large fish), kingfisher (feed on small fish), pelicans (concentrate at mouth of Bayou d'Inde), terns	Contaminant levels in tissues of prey species. Tissue residues and biomarkers in eggs and other tissues. Behavioral abnormalities. Reproductive success. Developmental abnormalities.
Aquatic-dependent mammals	Survival and Reproduction	Dolphins, river otter, mink, raccoons	Contaminant levels in tissues of prey species. Tissue residue levels in raccoon tissues. Presence/absence of sensitive species (i.e., in habitats that would be expected to support those species).

Table 8.2. Candidate assessment and measurement endpoints for toxic substances that partition into sediments (MacDonald *et al.* 2000a).

Receptor	Assessment Endpoint	Focal Species	Candidate Measurement Endpoints
Decomposers	Processing of Organic Carbon	Bacteria	Metabolic rate of bacteria (using Microtox as surrogate). Ammonia production rate. Changes on functional groups (Burton and Stemmer 1988). Porewater chemistry compared to toxicity thresholds.
Aquatic plants	Survival and Growth	Rooted aquatic plants (*Spartina)* and other macrophytes, algae	Survival and growth of indicator species (acute toxicity tests). Sediment chemistry compared to toxicity thresholds. Comparison of sensitivity of plants to invertebrates in water-only toxicity tests. Distribution and abundance of aquatic plants (salinity and others could be confounding factors).
Benthic invertebrates	Survival and Growth	Epifauna - shrimp, crabs infauna - copepods, amphipods	Survival and growth of the amphipod *Hyalella azteca* (10-d WS[1] test). Survival and growth of the amphipod *Hyalella azteca* (28-d WS test). Survival and growth of the amphipod *Ampelisca abdita* (10-d WS test). Fertilization and development of the sea urchin *Arbacia sp* . (PW[2] test). Sediment chemistry compared to SQGs[3]. Porewater chemistry compared to toxicity thresholds. Benthic invertebrate community structure. Sediment quality triad evaluation.
Benthic fish	Survival, Growth, and Reproduction	Redfish (benthic feeder), black drum (mollusc and sediment ingestion), flounder (pelagic feeder), gobis, blennies, killifish	Fish community status (creel or targeted surveys). Sediment chemistry compared to SQGs. Biomarkers in carnivorous fish tissues. Fecundity (i.e., in killifish). Fish health (% incidence of DELT abnormalities)[4]. Survival, development, growth in killifish or silversides (embryo-larval toxicity tests).

Table 8.2. Candidate assessment and measurement endpoints for toxic substances that partition into sediments (MacDonald *et al.* 2000a).

Receptor	Assessment Endpoint	Focal Species	Candidate Measurement Endpoints
Reptiles	Survival, Growth, and Reproduction	Alligators, snapping turtles, snakes	None suggested.
Amphibians	Survival, Growth, and Reproduction	Bull frogs, leopard frogs, pig frogs	Survival and growth of frogs (acute toxicity tests). Sediment chemistry compared to SQGs.
Sediment-probing birds	Survival and Reproduction	Sandpipers, willet, spoonbills, stilts, idis, ducks	Sediment chemistry compared to SQGs. Tissue chemistry in prey.

[1]WS = whole sediment

[2]PW = porewater

[3]SQG = sediment quality guideline

[4]DELT = deformities, fin erosion, lesions, and tumors.

Table 8.3. Candidate assessment and measurement endpoints for toxic substances that partition into overlying water (MacDonald *et al.* 2000a).

Receptor	Assessment Endpoint	Focal Species	Candidate Measurement Endpoints
Aquatic plants	Survival and Growth	Rooted aquatic plants (*Spartina)* and other macrophytes, algae	Survival and growth of indicator species (acute toxicity tests). Sediment chemistry compared to toxicity thresholds. Comparison of sensitivity of plants to invertebrates in water-only toxicity tests. Distribution and abundance of aquatic plants (salinity and others could be confounding factors).
Aquatic invertebrates	Survival and Growth	Epibenthic species, such as shrimp and crabs	Survival and growth of indicator species (acute toxicity test). Water chemistry compared to toxicity thresholds.
Fish	Survival, Growth, and Reproduction	Redfish, black drum, seatrout, flounder, gar, croaker, gobis, blennies, killifish	Survival and growth of indicator species (acute toxicity test). Water chemistry compared to toxicity thresholds. Fish health (% incidence of DELT abnormalities)[1].

[1]DELT = deformities, fin erosion, lesions, and tumors.

Table 8.4. Candidate assessment and measurement endpoints for toxic substances that partition into the surface microlayer (MacDonald *et al.* 2000a).

Receptor	Assessment Endpoint	Focal Species	Candidate Measurement Endpoints
Aquatic invertebrates	Survival and Growth	Decapod larvae, water striders, mosquito larvae	Survival and growth of indicator species (acute toxicity test). Water chemistry compared to toxicity thresholds.
Pelagic fish	Survival, Growth, and Reproduction	Menhaden, seatrout egg (which float)	Survival and growth of indicator species (acute toxicity test). Water chemistry compared to toxicity thresholds. Fish health (% incidence of DELT abnormalities)[1].

[1]DELT = deformities, fin erosion, lesions, and tumors.

Table 9.1. Testable hypotheses and measurement endpoints for assessing risk to plants and invertebrates.

Assessment Endpoint	Risk Questions (Testable Hypotheses)	Measurement Endpoints
Activity of the Microbial Community (e.g., rate of carbon processing by decomposers)	Is the metabolic rate of bacteria (i.e., the activity of aquatic microbiota) exposed to whole sediments from the Calcasieu Estuary significantly lower (P<0.1) than that for bacteria exposed to reference sediments?	Bioluminescence of bacterium, *Vibrio fisheri* (Microtox; as a surrogate for bacterial metabolic rate), in whole sediment toxicity tests (Johnson 1998; Johnson and Long 1998).
Survival and Growth of Aquatic Plants	Is the survival and/or growth of aquatic plants exposed to porewater from Calcasieu Estuary sediments significantly lower (P<0.1) than that for aquatic plants exposed to porewater from reference sediments?	Germination, germling length, and cell number of the alga, *Ulva lactuca* (as surrogates for survival, growth and reproduction), in porewater toxicity tests (Hooten and Carr 1998).
Survival, Growth and Reproduction of Benthic Invertebrates	Are the levels of contaminants in whole sediments from the Calcasieu Estuary greater than the sediment quality benchmarks for the survival, growth or reproduction of benthic invertebrates?	Concentrations of contaminants in whole sediments (i.e., reported on a dry weight basis, relative to sediment quality benchmarks for survival, growth or reproduction expressed as mean SQG-quotients; Table 9.2; USEPA 2000c; Long *et al.* 1995; Long and Morgan 1991; MacDonald *et al.* 1996).
	Are the levels of contaminants in porewater from Calcasieu Estuary sediments greater than the toxicity thresholds for survival, growth or reproduction of benthic invertebrates?	Concentrations of contaminants in porewater (i.e., relative to acute and chronic toxicity thresholds for survival and/or growth in porewater; USEPA 1999a).
	Is the survival of benthic invertebrates exposed to whole sediments from the Calcasieu Estuary significantly lower (P<0.1) than that of benthic invertebrates exposed to reference sediments?	Survival of the amphipod, *Hyalella azteca,* in 10-d whole sediment toxicity tests (ASTM 2000a); Survival of the amphipod, *Hyalella azteca*, in 28-d whole sediment toxicity tests (USEPA 2000d); Survival of the amphipod, *Ampelisca abdita,* in 10-d whole sediment toxicity tests (ASTM 2000b); Survival of the polychaete, *Nereis virens*, in 28-d whole sediment toxicity tests (ASTM 2000c).

Table 9.1. Testable hypotheses and measurement endpoints for assessing risk to plants and invertebrates.

Assessment Endpoint	Risk Questions (Testable Hypotheses)	Measurement Endpoints
Survival, Growth and Reproduction of Benthic Invertebrates (cont.)	Is the growth of benthic invertebrates exposed to whole sediments from the Calcasieu Estuary significantly lower ($P<0.1$) than that of benthic invertebrates exposed to reference sediments?	Growth of the amphipod, *Hyalella azteca* , in 10-d whole sediment toxicity tests (ASTM 2000a); Growth of the amphipod, *Hyalella azteca,* in 28-d whole sediment toxicity tests (USEPA 2000d).
	Is the reproductive success of benthic invertebrates exposed to porewater from Calcasieu Estuary sediments significantly lower ($P<0.1$) than that of benthic invertebrates exposed to porewater from reference sediments?	Fertilization and embryo development of the sea urchin, *Arbacia punctulata* (as a surrogate for reproductive success in benthic invertebrates), in porewater toxicity tests (Carr and Chapman 1992; Carr *et al.* 1996a; 1996b;1997).
	Is the structure of benthic macroinvertebrate communities in Calcasieu Estuary sediments outside the normal range for benthic invertebrate communities in reference sediments (i.e., 95% C.I.)?	Percent annelid abundance, percent arthropod abundance, and index of contamination, as calculated from raw species counts (Gaston and Nasci 1988; Gaston *et al.* 1988; Gaston and Young 1992; Brown *et al.* 2000).

Table 9.2. Summary of the effect-based sediment quality guidelines for the protection of aquatic life to be applied in the Calcasieu Estuary.

Contaminant of Potential Concern	Sediment Quality Guidelines		
	Marine/Estuarine		Freshwater
	Effects Range Median[1]	Probable Effect Level[2]	Probable Effect Concentration[3]
Metals (mg/kg)			
Chromium	370	160	111
Copper	270	108	149
Lead	218	112	128
Mercury	0.71	0.7	1.06
Nickel	51.6	42.8	48.6
Zinc	410	271	459
Polycyclic Aromatic Hydrocarbons (PAH; µg/kg)			
Low Molecular Weight (LMW)			
2-Methylnaphthalene	670	201	NG[4]
Acenaphthene	500	88.9	NG
Acenaphthylene	640	128	NG
Anthracene	1100	245	845
Fluorene	540	144	536
Naphthalene	2100	391	561
Phenanthrene	1500	544	1170
Total LMW-PAHs	3160	1442	NG
High Molecular Weight (HMW)			
Benz[a]anthracene	1600	693	1050
Benzo(a)pyrene	1600	763	1450
Chrysene	2800	846	1290
Dibenz[a,h]anthracene	260	135	NG
Fluoranthene	5100	1494	2230
Pyrene	2600	1398	1520
Total HMW-PAHs	9600	6676	NG
Total PAHs	44792	16770	22800
Polychlorinated Biphenyls (PCBs; µg/kg)			
Total PCBs	180	189	676

Table 9.2. Summary of the effect-based sediment quality guidelines for the protection of aquatic life to be applied in the Calcasieu Estuary.

Contaminant of Potential Concern	Sediment Quality Guidelines		
	Marine/Estuarine		Freshwater
	Effects Range Median[1]	Probable Effect Level[2]	Probable Effect Concentration[3]
Organochlorine Pesticides (µg/kg)			
Aldrin	NG	NG	NG
Dieldrin	8	4.3	61.8
Phthalates (µg/kg)			
Bis(2-ethylhexyl) phthalate	NG	2647	NG
Chlorinated Benzenes (µg/kg)			
Hexachlorobenzene	NG	NG	NG
Hexachlorobutadiene	NG	NG	NG
Chlorinated ethanes (µg/kg)			
1,2-dichloroethane	NG	NG	NG
Trichloroethane	NG	NG	NG
Other Substances			
Acetone	NG	NG	NG
Carbon disulfide	NG	NG	NG
Hydrogen sulfide	NG	NG	NG
Unionized ammonia (NH_3)	NG	NG	NG

[1]Long *et al.* 1995; Long and Morgan 1991

[2]MacDonald *et al.* 1996

[3]MacDonald *et al.* 2000b

[4]NG, no guideline available.

Table 9.3. Summary of the water quality criteria for the protection of aquatic life for the contaminants of potential concern in the Calcasieu Estuary (USEPA 1999a).

Contaminant of Potential Concern	Marine		Freshwater	
	CMC[1]	CCC[2]	CMC[1]	CCC[2]
Metals[3] (mg/L)				
Chromium III[4]	NG[18]	NG	570[5]	74[5]
Chromium IV	1100[6]	50[6]	16[5]	11[5]
Copper[4]	4.8[7,8]	3.1[7,8]	13[5,7]	9.0[5,7]
Lead[4]	210[6]	8.1[6]	65[6,9]	2.5[6,9]
Mercury	1.8[10,11]	0.94[10,11]	1.4[5,10]	0.77[5,10]
Nickel[4]	74[6]	8.2[6]	470[5]	52[5]
Zinc[4]	90[6]	81[6]	120[5]	120[5]
Polycyclic Aromatic Hydrocarbons (PAH; µg/kg)				
Low Molecular Weight (LMW)				
2-Methylnaphthalene	NG	NG	NG	NG
Acenaphthene	NG	NG	NG	NG
Acenaphthylene	NG	NG	NG	NG
Anthracene	NG	NG	NG	NG
Fluorene	NG	NG	NG	NG
Naphthalene	NG	NG	NG	NG
Phenanthrene	NG	NG	NG	NG
Total LMW-PAHs	NG	NG	NG	NG
High Molecular Weight (HMW)				
Benz[a]anthracene	NG	NG	NG	NG
Benzo(a)pyrene	NG	NG	NG	NG
Chrysene	NG	NG	NG	NG
Dibenz[a,h]anthracene	NG	NG	NG	NG
Fluoranthene	NG	NG	NG	NG
Pyrene	NG	NG	NG	NG
Total HMW-PAHs	NG	NG	NG	NG
Total PAHs	NG	NG	NG	NG
Polychlorinated Biphenyls (PCBs; µg/kg)				
Total PCBs[12,13]	NG	0.03	NG	0.014

Table 9.3. Summary of the water quality criteria for the protection of aquatic life for the contaminants of potential concern in the Calcasieu Estuary (USEPA 1999a).

Contaminant of Potential Concern	Marine CMC[1]	Marine CCC[2]	Freshwater CMC[1]	Freshwater CCC[2]
Organochlorine Pesticides (µg/kg)				
Aldrin[14]	1.3	NG	3.0	NG
Dieldrin	0.71[14]	0.0019[13,14]	0.24[5]	0.056[5,15]
Phthalates (µg/kg)				
Bis(2-ethylhexyl) phthalate	NG	NG	NG	NG
Chlorinated Benzenes (µg/kg)				
Hexachlorobenzene	NG	NG	NG	NG
Hexachlorobutadiene	NG	NG	NG	NG
Chlorinated ethanes (µg/kg)				
1,2-dichloroethane	NG	NG	NG	NG
Trichloroethane	NG	NG	NG	NG
Other Substances				
Acetone	NG	NG	NG	NG
Carbon disulfide	NG	NG	NG	NG
Hydrogen sulfide	NG	2.0[16]	NG	2.0[16]
Unionized ammonia (NH_3)[17]	pH & temperature dependent		pH dependent	

[1]CMC, Criteria Maximum Concentration (USEPA 1999a)

[2]CCC, Criterion Continuous Concentration (USEPA 1999a)

[3]Freshwater and marine criteria for metals are expressed in terms of the dissolved metal in the water column.

[4]The freshwater criterion for this metal is expressed as a function of hardness (mg/L) in the water column. The value given here corresponds to a hardness of 100 mg/L.

[5]These recommended criteria are based on 304(a) aquatic life criteria (EPA-820-B-96-001, September 1996).

[6]This water quality criterion is based on a 304(a) aquatic life criterion that was derived using the 1985 Guidelines.

[7]When the concentration of dissolved organic carbon is elevated, copper is substantially less toxic and use of Water-Effect Ratios might be appropriate.

[8]These recommended water quality criteria were derived in Ambient Water Quality Criteria Saltwater Copper Addendum (Draft, April 14, 1995) and was promulgated in the Interim final National Toxics Rule (60FR22228-222237,

Table 9.3. Summary of the water quality criteria for the protection of aquatic life for the contaminants of potential concern in the Calcasieu Estuary (USEPA 1999a).

Contaminant of Potential Concern	Marine		Freshwater	
	CMC[1]	CCC[2]	CMC[1]	CCC[2]

May 4, 1995)

[9]EPA is actively working on this criterion and so this recommended water quality criterion may change substantially in the near future.

[10]This recommended water quality criterion was derived from data for inorganic mercury (II), but is applied here to total mercury.

[11]This recommended water quality criterion was derived in the mercury criteria document *EPA 440/5-84-026, January 1985).

[12]PCBs are a class of chemicals which include aroclors, 1242, 1254, 1221, 1232, 1248, 1260, and 1016.

[13]This CCC is based on the Final Residue Value procedure in the 1985 Guidelines

[14]This criterion is based on 304(a) aquatic life criterion issued in 1980.

[15]The derivation of the CCC for this pollutant did not consider exposure through the diet, which is probably important for aquatic life occupying upper trophic levels.

[16]The derivation of this value is presented in the Red Book (EPA 440/5-88-001, July, 1976).

[17]According to the procedures described in the Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses, except possible where a very sensitive species is important at a site, freshwater aquatic life should be protected if both conditions specified in Appendix C to the Preamble-Calculation of Freshwater Ammonia Criterion are satisfied.

[18]NG, no guideline available.

Table 9.4. Testable hypotheses and measurement endpoints for assessing risk to benthic fish.

Assessment Endpoint	Risk Questions (Testable Hypotheses)	Measurement Endpoints
Survival, Growth, and Reproduction of Benthic and Pelagic Fish	Are the concentrations of contaminants in overlying water from the Calcasieu Estuary greater than the water quality benchmarks for the survival, growth, or reproduction of fish?	Concentrations of contaminants in overlying water (i.e., relative to the water quality criteria for the protection of aquatic organisms; Table 9.3; USEPA 1999a).
	Are the concentrations of contaminants in porewater from Calcasieu estuary sediments greater than the water quality benchmarks for the survival, growth, or reproduction of fish?	Concentrations of contaminants in porewater (i.e., relative to the water quality criteria for the protection of aquatic organisms; Table 9.3; USEPA 1999a).
	Is the survival of fish (as indicated by the survival of redfish larvae) exposed to porewater from Calcasieu Estuary sediments significantly lower (P<0.1) than that of fish exposed to porewater from reference sediments?	Survival of redfish, *Sciaenops ocellatus*, larvae in 48-h porewater toxicity tests (Carr and Chapman 1992).
	Is the reproductive success of fish (as indicated by hatching success) exposed to porewater from Calcasieu Estuary sediments significantly (P<0.1) lower than that of fish exposed to porewater from reference sediments?	Hatching success of redfish, *Sciaenops ocellatus*, eggs in 24-h porewater toxicity tests (Carr and Chapman 1992).

Table 9.5. Testable hypotheses and measurement endpoints for assessing risk to avian and mammalian wildlife.

Assessment Endpoint	Risk Questions (Testable Hypotheses)	Measurement Endpoints
Survival and Reproduction of Aquatic-Dependent Bird Species	Are the levels of contaminants in the tissues of prey species of sediment-probing birds in the Calcasieu Estuary higher than the tissue residue benchmark values for survival or reproduction?	Concentrations of contaminants in the tissues of benthic invertebrates (i.e., relative to tissue residue benchmarks for selected focal wildlife species; Table 9.6).
	Are the levels of contaminants in the tissues of prey species of carnivorous wading birds in the Calcasieu Estuary higher than the tissue residue benchmark values for survival or reproduction?	Concentrations of contaminants in the tissues of benthic invertebrates and fish (i.e., relative to tissue residue benchmarks for selected focal wildlife species; Table 9.6).
	Are the levels of contaminants in the tissues of prey species of piscivorus birds in the Calcasieu Estuary higher than the tissue residue benchmark values for survival or reproduction?	Concentrations of contaminants in the tissues of fish (i.e., relative to tissue residue benchmarks for selected focal wildlife species; Table 9.6).
Survival and Reproduction of Aquatic-Dependent Mammal Species	Are the levels of contaminants in the tissues of prey species of omnivorous mammals in the Calcasieu Estuary higher than the tissue residue benchmark values for survival or reproduction?	Concentrations of contaminants in the tissues of benthic invertebrates and pelagic invertebrates (i.e., relative to tissue residue benchmarks for selected focal wildlife species; Table 9.6).
	Are the levels of contaminants in the tissues of prey species of piscivorus mammals in the Calcasieu Estuary higher than the tissue residue benchmark values for survival or reproduction?	Concentrations of contaminants in the tissues of invertebrates and fish (i.e., relative to tissue residue benchmarks for selected focal wildlife species; Table 9.6).

Table 9.6. Toxicity reference values (TRV) for selected wildlife focal species (Sample *et al.* 1996).

Chemical (form)	Test Species	NOAEL-based TRV[a] (mg/kg/d)
Acetone	Rat	10
Aldrin	Rat	0.2
Aroclor 1254	Oldfield mouse	0.068
	Mink	0.14
	Ring-necked pheasant	0.18
Benzo(a)pyrene	Mouse	1
Bis(2-ethylhexyl)phthalate	Mouse	18.3
	Ringed dove	1.1
Chromium [Cr^{+3} as $CrK(SO_4)^2$]	Black duck	1
Chromium (Cr^{+6})	Rat	3.28
Copper	Mink	11.7
	Chicks (species not specified)	47
1,2-Dichloroethane	Mouse	50
	Chicken	17.2
Dieldrin	Rat	0.02
	Barn owl	0.077
Lead (lead acetate)	Rat	8
	Japanese quail	1.13
Mercury (inorganic)	Mouse	13.2
	Mink	1
	Japanese quail	0.45

Table 9.6. Toxicity reference values (TRV) for selected wildlife focal species (Sample *et al.* 1996).

Chemical (form)	Test Species	NOAEL-based TRV[a] (mg/kg/d)
Acetone	Rat	10
Mercury (methylmercury)	Rat	0.032
	Mink	0.015
	Mallard duck	0.0064
Nickel	Rat	40
	Mallard suckling	77.4
1,1,1-Trichloroethane	Mouse	1000
Zinc (zinc oxide)	Rat	160
Zinc (zinc sulfate)	White leghorn hen	14.5

[a] Where the data permit, TRVs will be made specific to birds, mammals or the assessment endpoint (e.g., mink)

Table 9.7. Example of a simple summary of a risk characterization by weight of evidence for a soil invertebrate community (adapted from Suter 1996).

Evidence	Result	Weight	Explanation
Biological Surveys	-	H	Soil microarthropod taxonomic richness is within the range of reference soils and is not correlated with concentrations of petroleum components.
Ambient Toxicity Tests	-	M	No reduction in the survival of the earthworm Eisenia foetida. Sublethal effects were not determined.
Organism Analyses	±	L	Concentrations of PAHs in depurated earthworms were elevated relative to worms from reference sites, but unknown whether elevated concentrations are associated with effects.
Soil Analyses/Single Chemical Tests	±	L	If the total hydrocarbon content of the soil is assumed to be composed of benzene only (an unlikely situation), then earthworm mortality is expected. Toxicity data for other detected contaminants are unavailable
Weight-of-Evidence	-	M	Although earthworm tests may not be sensitive, they and the biological surveys are both negative and are both more reliable than the comparison of single chemical toxicity data with soil analytical results

+ Evidence is consistent with the occurrence of a 20% reduction in species richness or abundance of the invertebrate comm
- Evidence is inconsistent with the occurrence of a 20% reduction in species richness of abundance of the invertebrate community

± Evidence is ambiguous

H=High, M=Medium, L=Low